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## CORRELATION OF THE STRENGTH AND DURABILITY OF SOUTHERN PINE

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### INTRODUCTION

It has been known for some time that the strength of pine structural timbers is a function of specific gravity (density). About twenty-five years ago Johnson<sup>1</sup> demonstrated by actual tests on longleaf pine (*Pinus palustris*) that there is a regular increase in average strength with an increase in density, and this is especially true where all of the pieces tested are reduced to a standard dryness. He also pointed out that compression endwise tests parallel with the grain give the best indication of the general strength value of the wood.

Since these earlier studies many testing laboratories have continued to establish relations between the physical and mechanical properties of wood. This is especially true of the Forest Products Laboratory maintained by the United States Forest Service and the Purdue University Laboratory for Testing Materials. The results of the tests made by the Forest Service and others were discussed by Betts<sup>2</sup> before the American Society for Testing Materials, and rules for grad-

<sup>1</sup> Johnson, J. B. Timber physics. Investigations on longleaf pine. 4. Results on mechanical tests. U. S. Dept. Agr., For. Div. Bul. 8: 22-31. f. 11-16. 1893.

<sup>2</sup> Betts, H. S. Discussion of the proposed Forest Service rules for grading the strength of southern pine structural timbers. Proc. Am. Soc. for Testing Materials 15: 369-384. f. 1-9. 1915.

ing the strength of southern pine structural timbers based on these various investigations were proposed. In general, these tests showed that as the density increases, the strength also increases in a uniform manner, and the density can be estimated by making use of the proportion of summer wood to spring wood in the annual rings. As the density is dependent on the summer wood, the percentage of summer wood is an index of weight and strength, and is an important guide in judging the quality of timber, independent of any defects it may contain. Tests made on pieces of summer wood and spring wood whittled out separately from broad rings of loblolly pine show that the strength and density of the summer wood is very close to double that of the spring wood. Thus there is a definite relation between strength and density of pine timbers.

In a recent paper the writer<sup>1</sup> reported results of experiments in which some important physical properties of southern pine woods were correlated with the decay induced by *Lenzites saepiaria*. Some of these results show that the specific gravity (density) of the wood materially influences resistance to decay of the heart-wood, the more dense pieces being more durable. By the correlation of the function which specific gravity of wood has thus been shown to play in its strength and durability, one would naturally conclude that when a timber possesses properties to make it strong, the chances are that it will be correspondingly durable. Although such inferences might be made, it was thought well to report the results of studies made on the resistance to fungous decay of timbers which had actually been tested for strength. The results of these experiments are reported below.

#### METHODS OF EXPERIMENTATION

Twelve samples each of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*) were procured, the longleaf pine from the Industrial Lumber Company, Elizabeth,

<sup>1</sup> Zeller, S. M. Studies in the physiology of the fungi. III. Physical properties of wood in relation to decay induced by *Lenzites saepiaria* Fries. Ann. Mo. Bot. Gard. 4: 93-164. pl. 9-13. f. 1. Charts I-XI. 1917.

Louisiana, and the shortleaf pine from the Missouri Land and Lumber Company, West Eminence, Missouri. All of the samples were  $4 \times 4$  inches, and each was sawed into two pieces, one of which was sent to the Laboratory for Testing Materials at Purdue University, and the other one retained for use in the preparation of culture blocks. The shortleaf pine samples were numbers 46-57, and the longleaf pine, 58-69, the cross-sections being shown in plates 7 and 8, respectively. The same methods of labeling culture blocks, kiln-drying, taking volumes, etc., were used here as were previously reported.<sup>1</sup> In this work the culture blocks were  $1 \times 1 \times 2$  inches. Four columns, A, B, C, and D, of five blocks each were used. The position of these in the original samples is shown in the plates.

The culture blocks were placed on end in wide-mouthed quart jars containing about one inch of pine sawdust. Then sawdust was loosely packed around the blocks and moistened with distilled water. The jars were plugged and sterilized as usual, and then the cultures were inoculated with *Lenzites saepiaria*. In this condition they were incubated for 6 months at room temperature. After this time it was apparent that they were not doing as well as in previous experiments where the blocks were not placed in sawdust, and the blocks were therefore removed, piled loosely in a clean pine box, and each layer inoculated anew with *Lenzites saepiaria* grown on pine sawdust. The whole was covered with a layer of damp sawdust which was slightly moistened from time to time. This box was stored in a humid rotting-pit for one year, making a total incubation period of 18 months. After this the blocks were removed, dried and weighed, and the percentage loss in weight during incubation is the index of decay used in plotting the curves shown in figs. 1, 2, and 3.

#### STRENGTH TESTS

A portion from each of the original samples was tested for strength at the Laboratory for Testing Materials, Purdue University. One specimen 6 inches in length from each  $4 \times 4$ -

<sup>1</sup> Zeller, S. M. *Loc. cit.* p. 102.

inch piece was soaked in water for a period of nine weeks. Another specimen 6 inches in length was cut into two sets of four smaller test pieces approximately  $1\frac{1}{8} \times 1\frac{1}{8} \times 3$  inches. One of these sets of smaller test specimens, comprising an entire cross-section of the original piece, was stored in wet shavings for a period of nine weeks. The other set was allowed to come to as uniform a moisture content as possible when stored in ordinary outside air, these being later referred to as air-dry specimens.

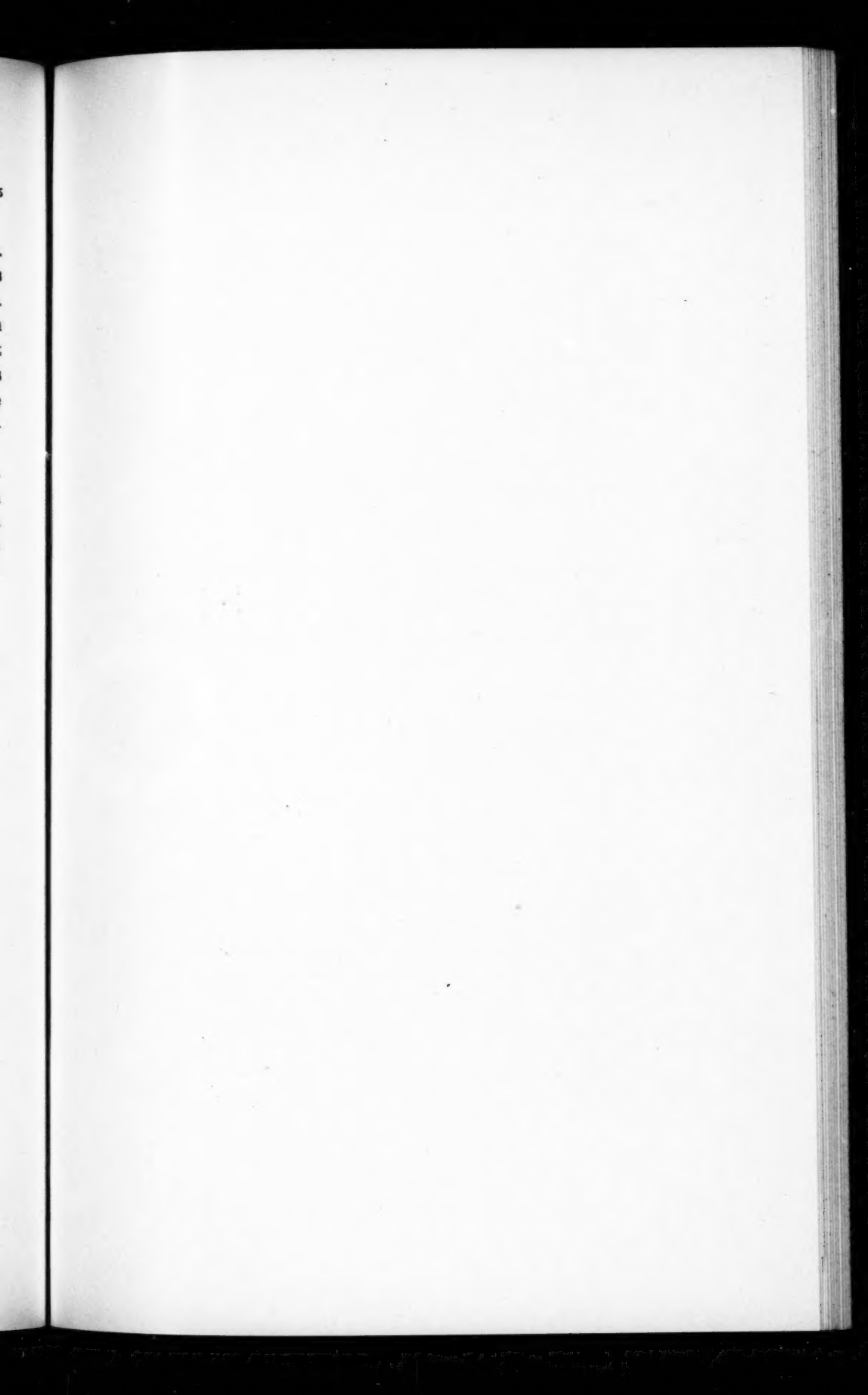
All specimens were tested by compression pressure endwise, the load being applied in a direction parallel to the grain of the wood. The maximum crushing load was obtained in each case and is given in table 1. The moisture content of all specimens was obtained by drying to a constant weight at approximately 210° F.

In the small wet blocks the moisture had thoroughly permeated the wood fiber, and the strength was more nearly coincident with the intrinsic strength of the timber as would have been given by tests of the specimens in a green condition. It also seems that the tests of the wet blocks are more indicative of the intrinsic strength of the wood, inasmuch as the air-dry pieces have non-uniform moisture distribution under the same atmospheric conditions. This condition would apply also to the absorption of water, except that the time of absorption was long enough to bring all of the pieces to a moisture content well above the fiber-saturation point (as shown by the percentage of moisture given in the table), in which case the tests should show the relative intrinsic strength without regard to the varying per cents of moisture as given.

Table 1 gives the results of both the decay and strength tests. The average percentage loss in weight due to decay was made on the number of heart-wood culture blocks from each sample. There was not enough sap-wood in the samples to be of use in drawing conclusions, thus the results reported here are based on heart-wood alone. However, in previous work<sup>1</sup> it has been shown that sap-wood decays irrespective

<sup>1</sup> Zeller, S. M. *Loc. cit.*





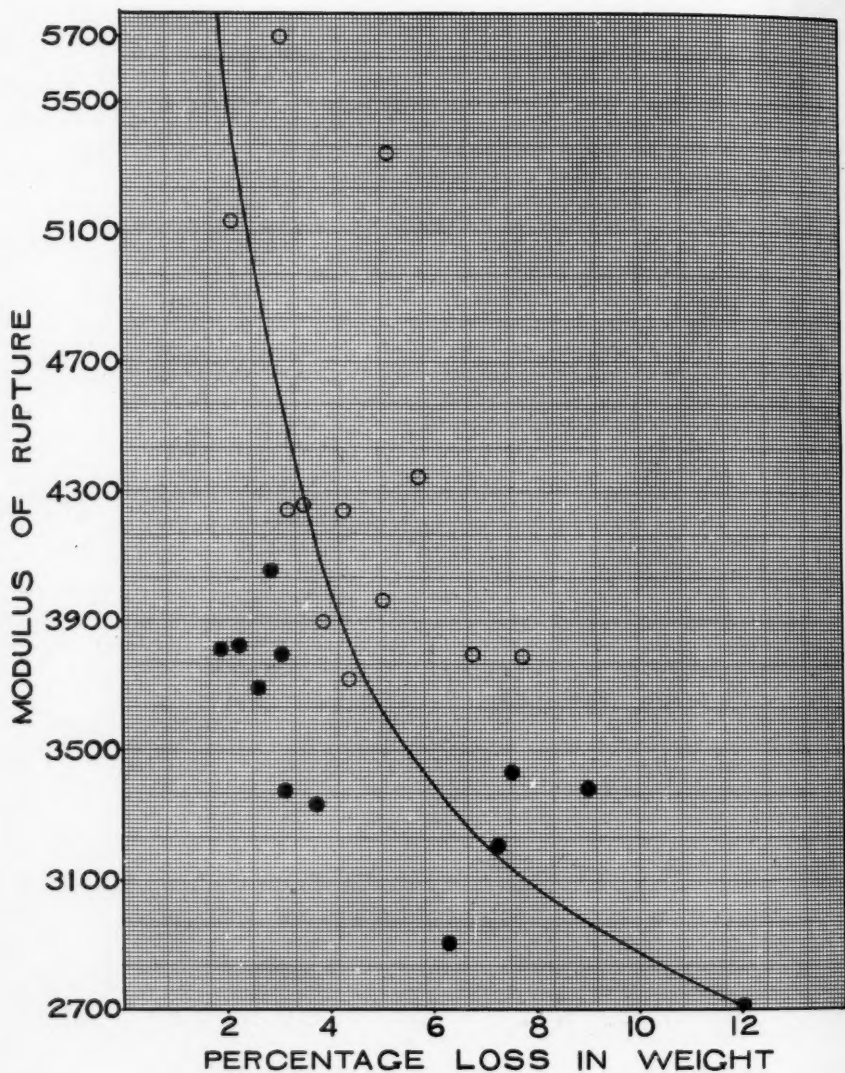


Fig. 1. Showing the relation between strength (when  $1\frac{1}{4} \times 1\frac{1}{4}$ -inch water-saturated blocks were tested) and percentage loss in weight due to the decay of longleaf (O) and shortleaf (●) pine.

of specific gravity or high percentage of summer wood, factors which function in the strength of the pieces.

TABLE I  
STRENGTH AND DURABILITY OF SOUTHERN PINE HEART-WOOD

Sample number	Average per cent loss in weight of heart-wood due to decay	Strength tests					
		Small blocks (wet)		Full-size blocks (wet)		Small blocks (dry)	
		Strength in pounds per square inch	Per cent moisture	Strength in pounds per square inch	Per cent moisture	Strength in pounds per square inch	Per cent moisture
Shortleaf pine ( <i>Pinus echinata</i> )							
46	3.13	3375	58.1	3050	50.7	6052	10.8
47	7.24	3207	63.8	2840	47.8	5080	12.8
48	2.85	4055	61.9	3655	47.4	5765	12.6
49	9.00	3380	47.5	3065	46.3	5962	10.4
50	7.52	3432	55.9	3550	53.9	6447	11.9
51	3.74	3332	40.1	3185	59.1	5605	11.1
52	2.24	3822	50.0	3770	45.4	7277	10.2
53	1.88	3812	50.7	3410	50.1	6142	11.3
54	12.02	2705	82.3	2440	43.6	3957	15.9
55	2.61	3692	67.5	3555	53.8	6160	14.0
56	6.29	2902	79.9	2790	54.0	5202	12.1
57	3.07	3795	56.9	3910	43.6	5817	13.8
Longleaf pine ( <i>Pinus palustris</i> )							
58	2.11	5130	25.2	5220	25.3	8032	13.5
59	3.19	4255	50.7	4290	41.3	7312	13.1
60	5.12	5340	26.0	5270	24.0	8812	10.6
61	5.72	4342	65.6	3990	58.4	7012	14.5
62	4.26	4240	67.1	4180	53.9	7817	13.5
63	3.06	5695	42.0	5540	40.2	8272	14.0
64	4.37	3720	57.7	3570	47.3	6635	13.1
65	6.76	3795	60.0	3690	56.1	6450	12.3
66	7.73	3790	81.6	4020	64.6	6467	13.7
67	3.50	4257	44.1	4130	39.6	7485	11.2
68	3.87	3897	43.4	3890	45.7	6897	10.3
69	5.03	3962	42.4	3910	46.1	7147	11.3

#### RESULTS AND CONCLUSIONS

The curves in figs. 1, 2, and 3 graphically represent the results presented in table I. Figure 1 shows the relation between strength and durability of pine heart-wood when the strength tests were made on  $1\frac{1}{8} \times 1\frac{1}{8}$ -inch water-saturated blocks. Figures 2 and 3 show the same relation when  $4 \times 4$ -inch water-saturated blocks and  $1\frac{1}{8} \times 1\frac{1}{8}$ -inch air-dry blocks, respectively, were tested for strength. The three strongest samples, 63, 60, and 58, show considerable loss in weight, which is not totally due to decay. They were highly resinous,

and some of the resin was lost in sterilizing under steam pressure. The curves are corrected for this error.

The curves in the three cases show that as the strength increases the durability increases. In order to refer to some specific instances, examine plate 7, showing the cross-sections of the original shortleaf pine samples, and notice numbers 48 and 53 in contrast with numbers 49 and 54. The former show a much higher percentage of dark summer wood and somewhat narrower growth rings in the heart-wood than in the latter. In the table, numbers 48 and 53 show a loss in weight due to decay of 2.85 and 1.88 per cent, respectively, and are relatively strong, while numbers 49 and 54 show a loss in weight from decay of 9 and 12.02 per cent, respectively, and are not nearly so strong as numbers 48 and 53. Other examples, such as contrasting numbers 46 with 56, 52 with 47, etc., will show this same relation of strength and decay. For instance, in plate 8, showing the original samples of longleaf pine, number 63 has narrow rings with a high percentage of summer wood, characters which are conducive to strength, in contrast to number 65, which has broad rings with a low percentage of summer wood. The strength tests show number 63 much stronger than 65, and the decay tests show a loss of 6.76 per cent in number 65 and 3.06 per cent in number 63. The same relation is shown when contrasting numbers 58 with 61, 59 with 64, 60 with 66, etc.

The results thus show that whether we are dealing with shortleaf pine or longleaf pine the stronger pieces of heart-wood are the more durable, and *vice versa*. This, however, does not apply to sap-wood, as it seems to decay irrespective of the amount of summer wood and specific gravity, which materially influence the strength of yellow pine sap-wood.

The writer wishes to express his appreciation to the Missouri Botanical Garden for the use of the laboratories; to the Southern Pine Association for providing funds which made this work possible; and to Dr. Hermann von Schrenk for suggesting this work and for his aid and interest.

*Graduate Laboratory, Missouri Botanical Garden.*

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5200  
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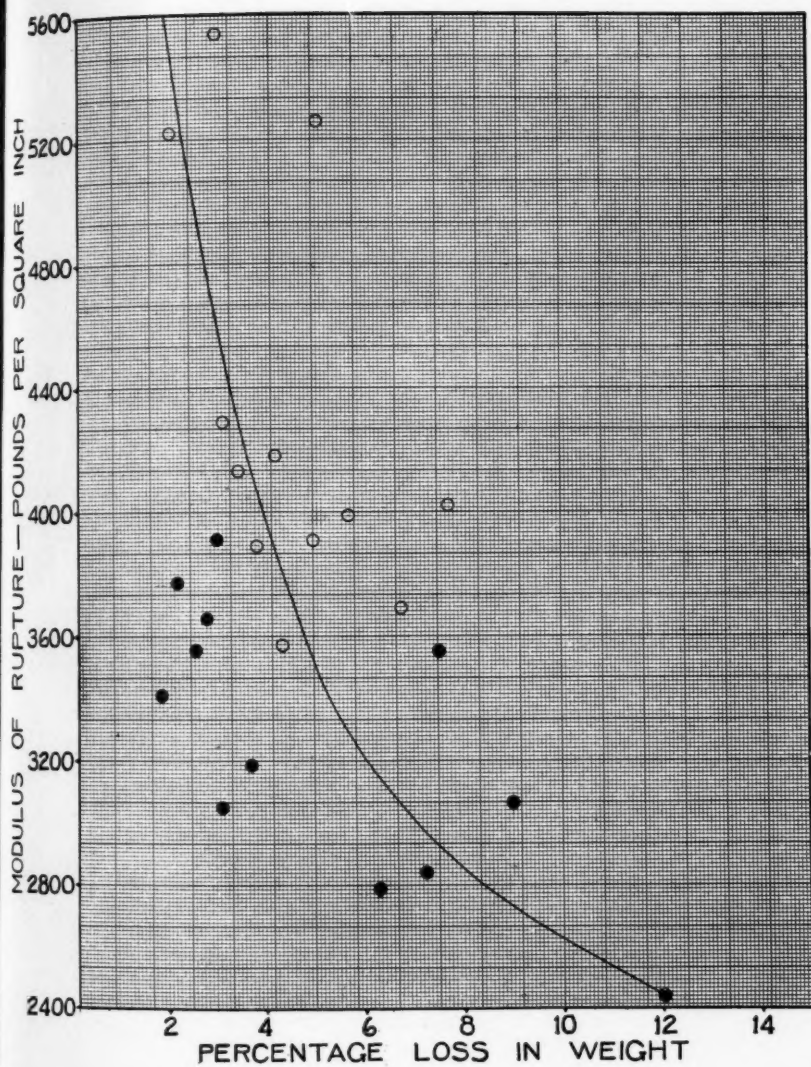


Fig. 2. Showing the relation between strength (when 4×4-inch water-saturated blocks were tested) and percentage loss in weight due to the decay of longleaf (○) and shortleaf (●) pine.



87

83

79

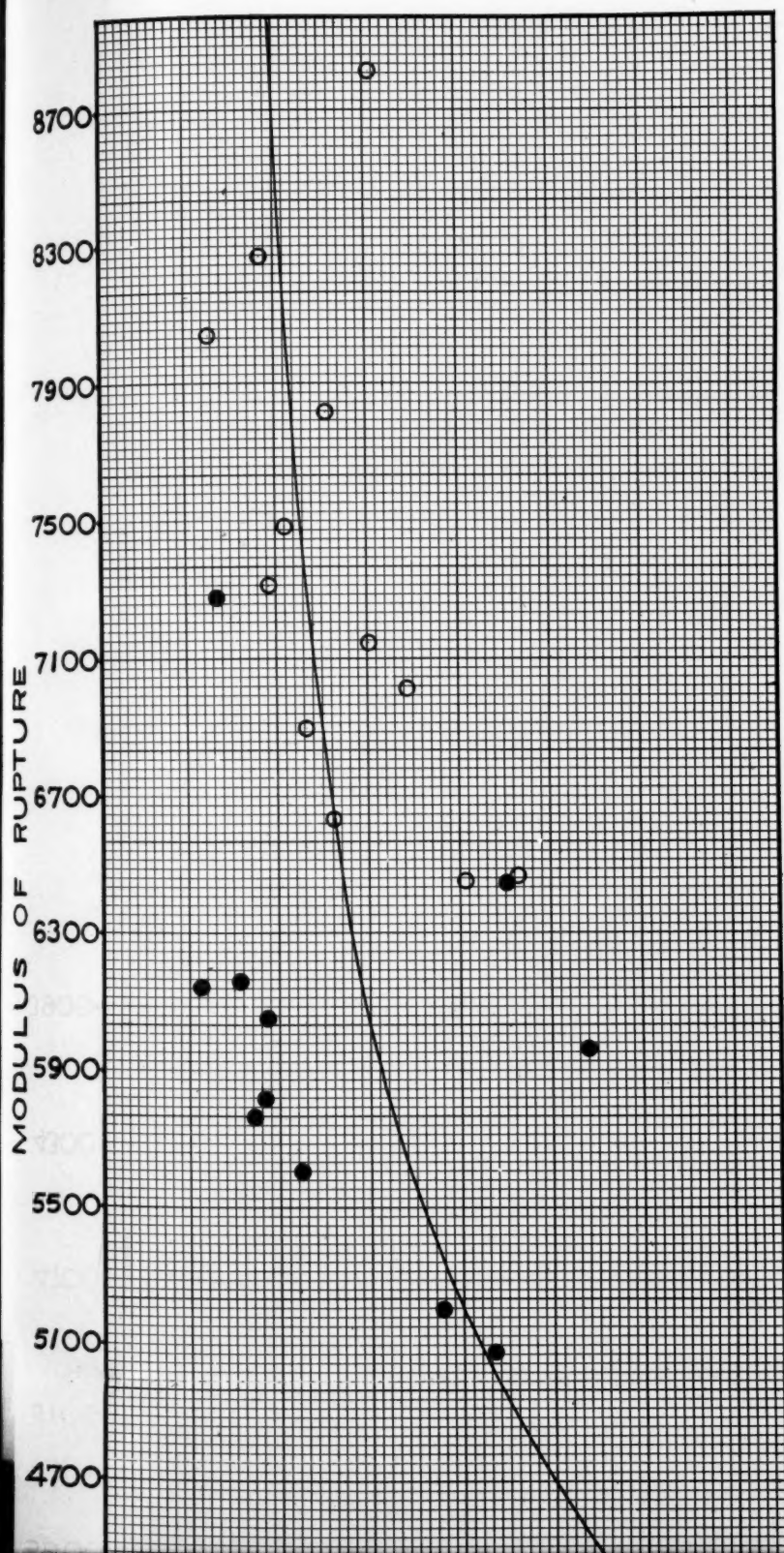
75

RUPTURE 7  
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55

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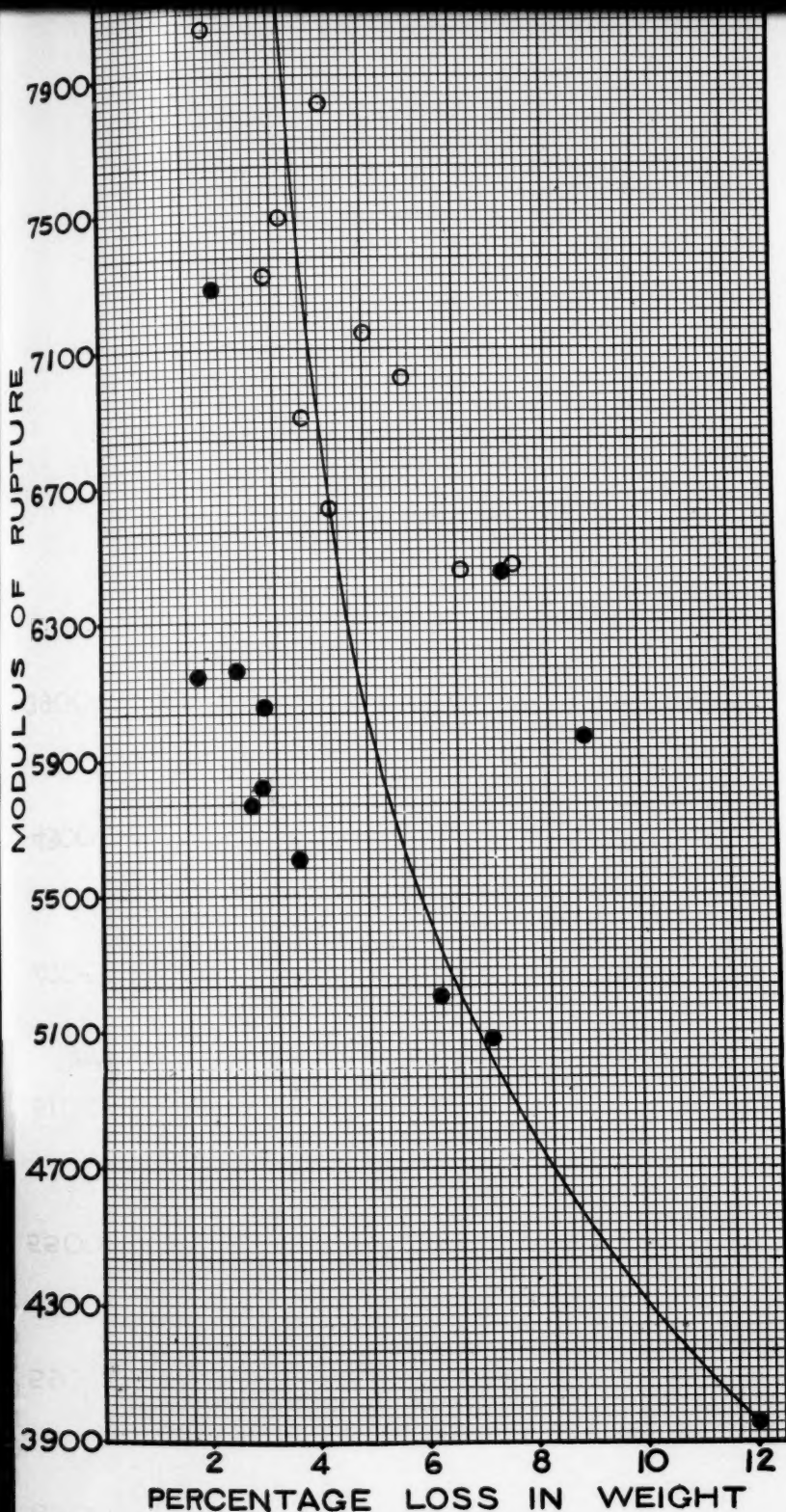
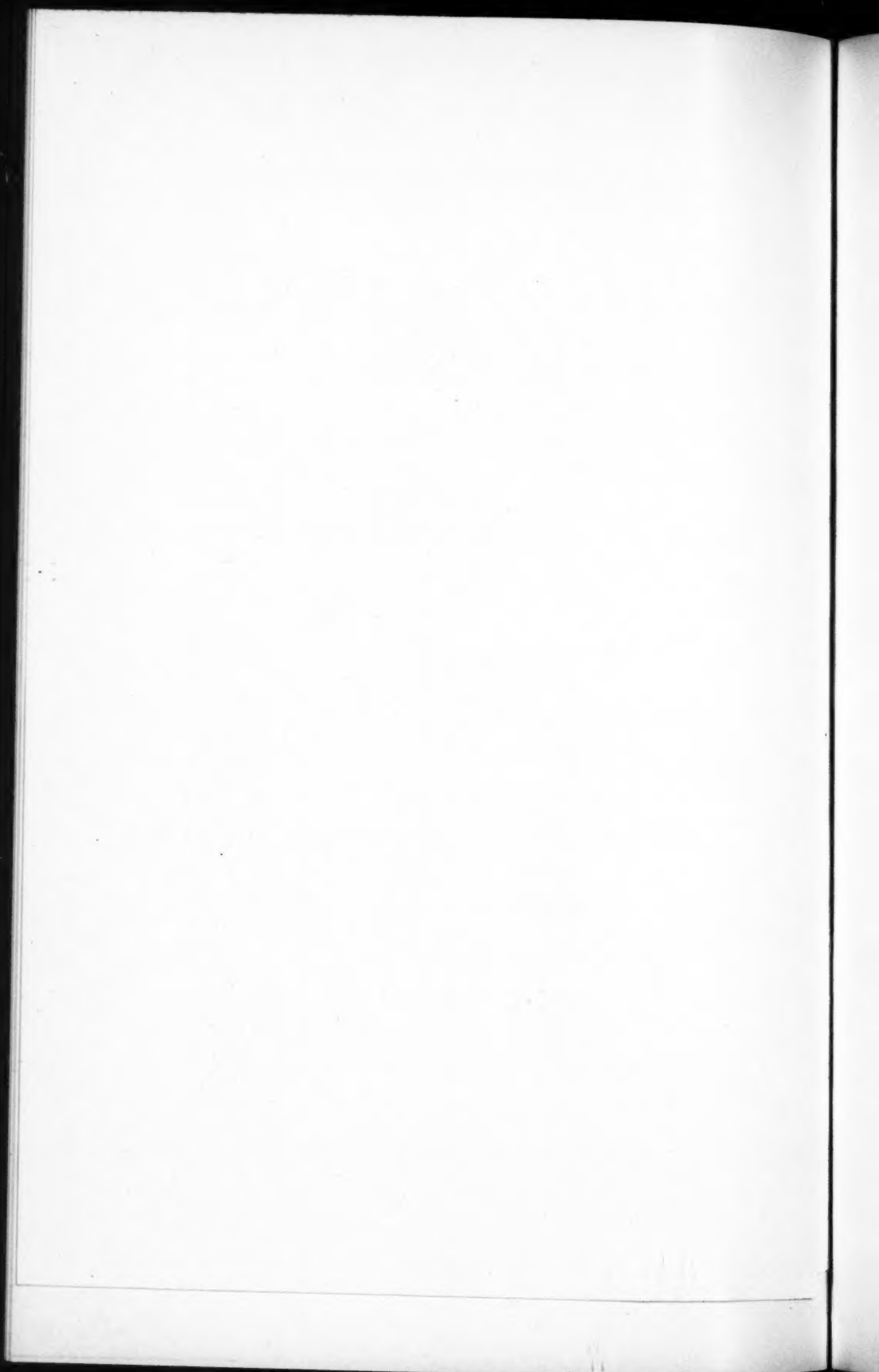
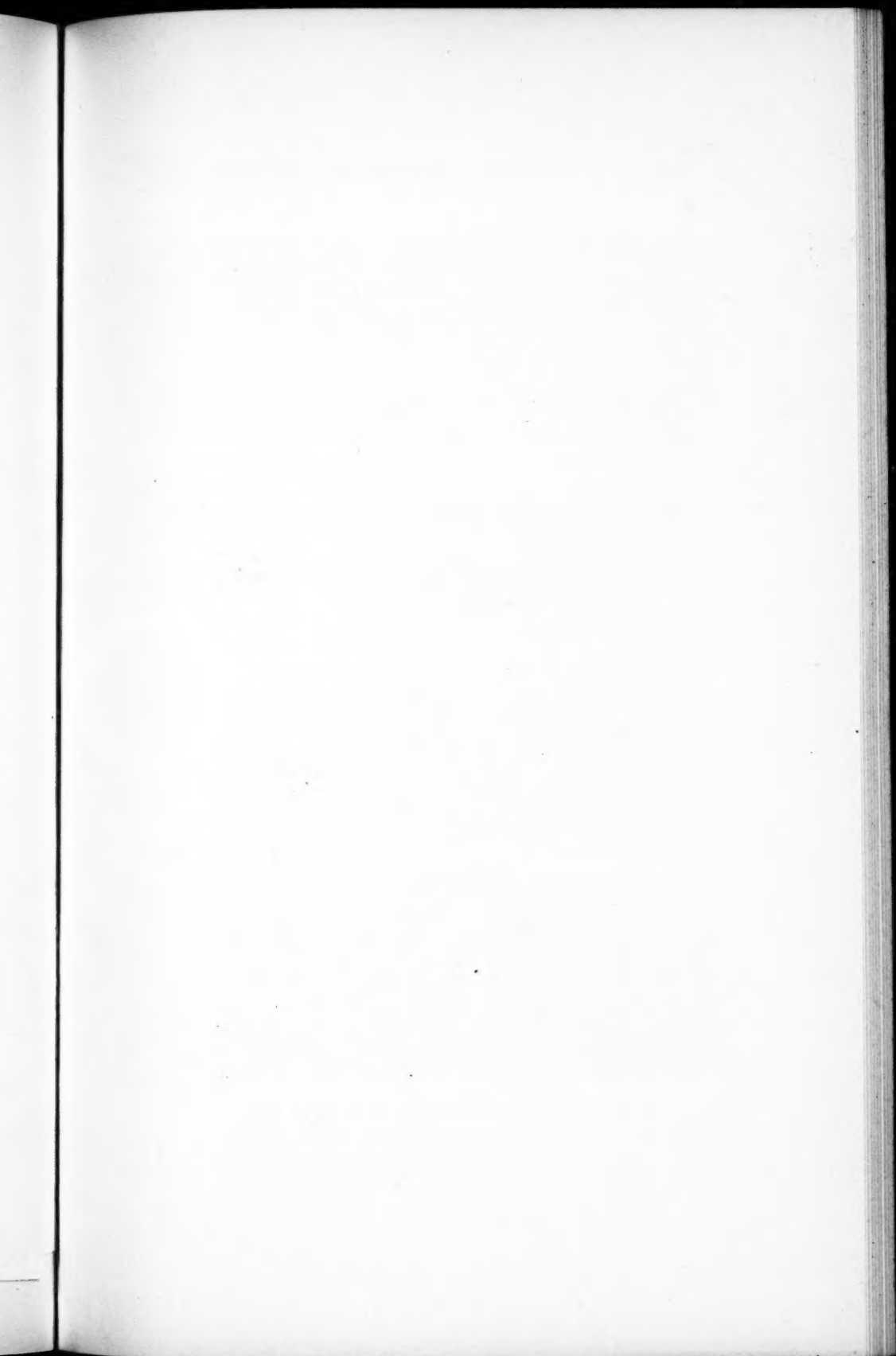


Fig. 3. Showing the relation between strength (when  $1\frac{1}{4} \times 1\frac{1}{4}$ -inch air-dry blocks were tested) and the percentage loss in weight due to the decay of longleaf (○) and shortleaf (●) pine.







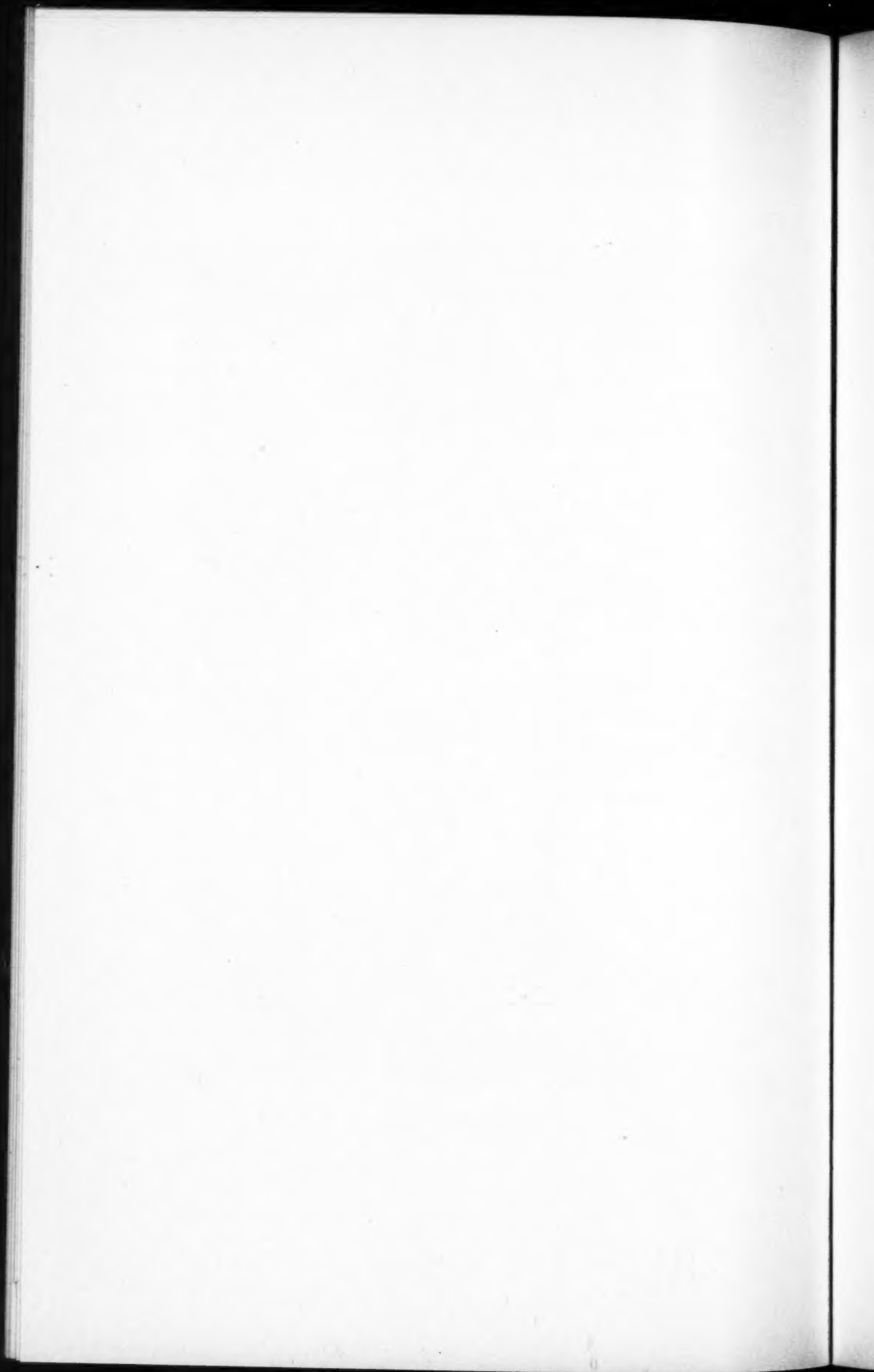
## EXPLANATION OF PLATE

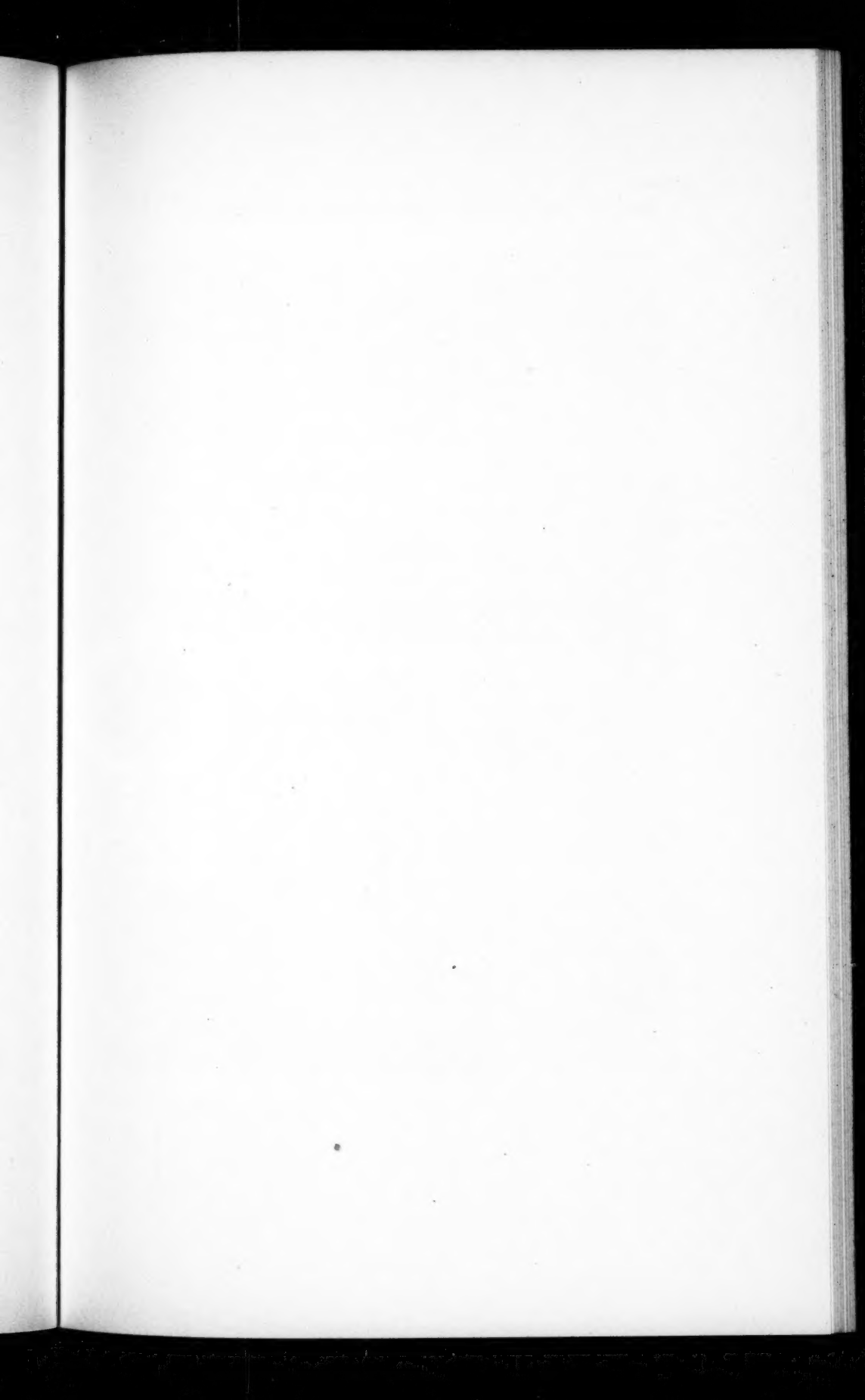
## PLATE 7

The original samples of shortleaf pine (*Pinus echinata*). The lettered squares are 1×1 inch and represent the columns of culture blocks used in the experiments.



ZELLER—STRENGTH AND DURABILITY OF PINE



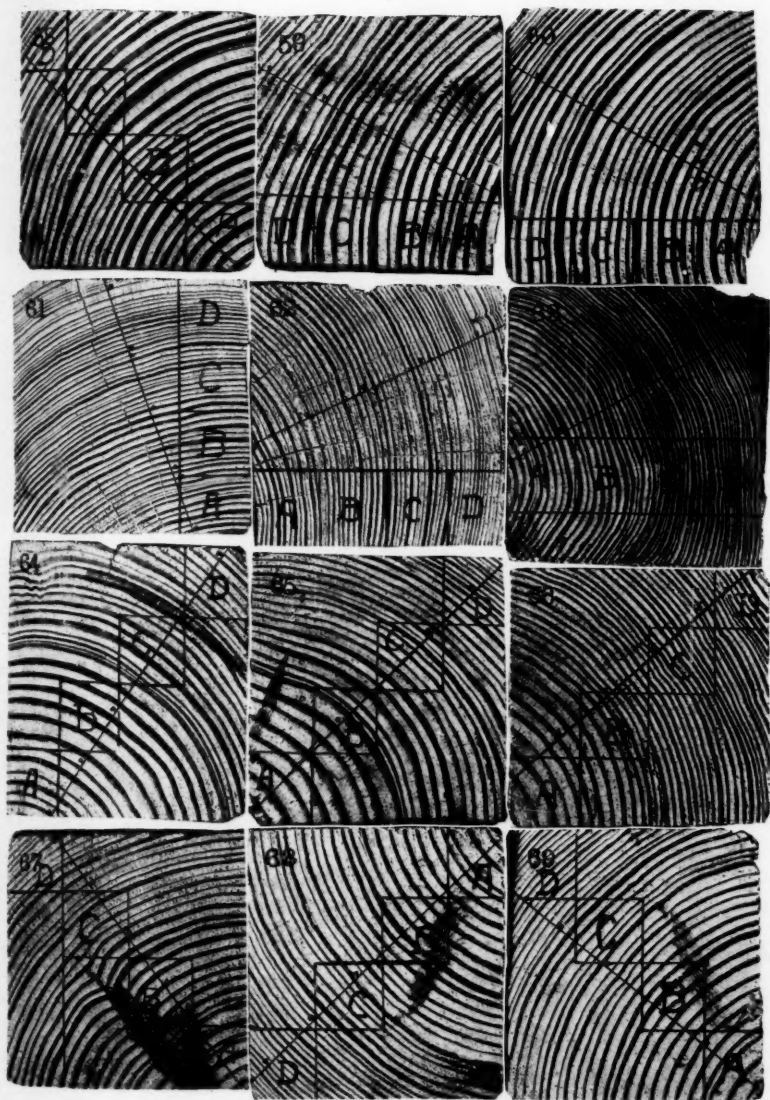




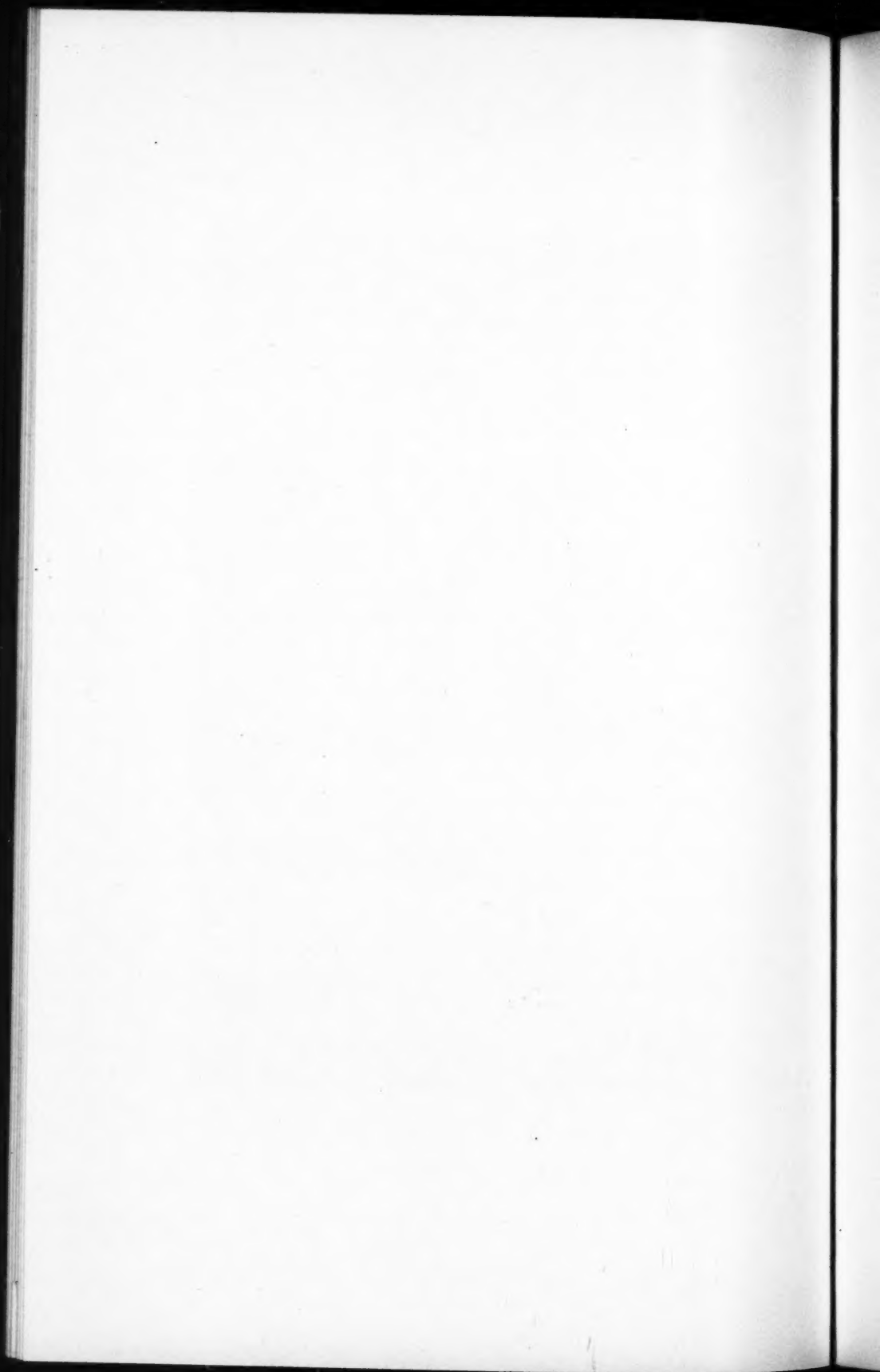
## EXPLANATION OF PLATE

## PLATE 8

The original samples of longleaf pine (*Pinus palustris*). The lettered squares are 1×1 inch and represent the columns of culture blocks used in the experiments.



ZELLER—STRENGTH AND DURABILITY OF PINE



CORTICIUMS CAUSING PELLICULARIA DISEASE OF  
THE COFFEE PLANT, HYPOCHNOSE OF  
POMACEOUS FRUITS, AND  
RHIZOCTONIA DISEASE<sup>1</sup>

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Last year Professor F. L. Stevens sent to the author specimens of coffee branches collected at Mayaguez, Porto Rico, August, 1915, which were infested with the *Pellicularia* fungus, and requested that study be made to determine whether this fungus is not one of the *Thelephoraceae*. In compliance with this request, preparations were made from the material, which finally afforded simple basidia bearing hyaline, even spores  $12 \times 4 \mu$ , flattened on one side. This fungus is a *Corticium* with habit of growth and structure greatly resembling the *Hypochnus ochroleucus* Noack which Dr. Stevens studied in 1907.

Upon looking up the literature of the *Pellicularia* fungus complications developed as follows:

1. *Pellicularia kôleroga* was published by M. C. Cooke, in 1876, as a hyphomycete having solitary, globose, echinulate spores situated here and there along the sides of the hyphae. In the article in *Popular Science Review* 15: 164-165, 1876, Cooke expresses doubt as to whether the globose bodies are spores, because they do not become detached from the hyphae, and believes that their true nature will have to be decided by germination experiments. The material upon which Cooke based his species was collected at Mysore, India.

2. Dr. A. Ernst studied diseases of coffee in Venezuela and published a paper in 1878, entitled "Estudios sobre las Deformaciones, Enfermedades y Enemigos del Arbol de Cafe in Venezuela," pp. 1-24. Caracas. One of the diseases consid-

<sup>1</sup> Issued May 24, 1918.

ered in the paper is named by Ernst as Candelillo, and its fungous cause is described rather fully by him as *Erysiphe scandens*, with an illustration of mycelium bearing conidia. Specimens of coffee leaves affected with "Candelillo" were sent to Kew Herbarium by Ernst; these specimens were studied by Cooke, who determined the fungus as his *Pellicularia koleroga*.

3. In 1912, Kuijper concluded that the fungous leaf blight of coffee in Porto Rico is distinct from that causing Candelillo in Venezuela and different from *Pellicularia koleroga* of India. Shortly afterward G. L. Fawcett obtained through E. J. Butler specimens of the coffee blight fungus from Mysore, the type locality, and concluded that the Porto Rican fungus agreed in every way with that from Mysore, but that the Venezuelan fungus is distinct. Neither of these authors noted the basidiomycetous nature of the fungus which they studied, although it is obvious from the illustration by Fawcett that he figured young basidia as hold-fast cells.

Upon writing to the Kew Herbarium for a fragment of the type of *Pellicularia koleroga* Cooke, in order that I might determine for the systematic account of North American species of *Corticium* the status of the *Corticium* parasitic upon coffee leaves at Mayaguez, the Director of Kew Herbarium kindly presented me with small portions of the Venezuelan specimens which had been received from Ernst and regretted that the Mysore specimen was now so fragmentary that only microscopical preparations from it could be spared. Miss Wakefield very kindly sent with these preparations drawings which she made of the basidia, spores, and hyphae from the above-mentioned preparation as soon as prepared, drawings of the same parts in the Ernst Candelillo specimen, similar drawings and portion of a specimen on coffee collected in Colombia by H. T. Dawe, and other drawings of the same organs based on Trinidad specimens collected by J. H. Hart.

The collections on coffee leaves made by Dr. Stevens and Mr. H. E. Thomas, at Mayaguez, Porto Rico, in August, 1915,



and in May, 1917, respectively, agree with the collections from Venezuela and Colombia in all respects except slight differences as to whether the hyphae are hyaline or slightly colored. In cross-sections of the leaves of all the specimens, fungous hyphae are present more or less abundantly between the cells of the leaf parenchyma and extending across the intercellular spaces of the leaf. Occasionally these hyphae may be traced outward to the under surface of the leaf, where they form a part of the layer, one to three hyphae thick, of hyphae running along the surface of the leaf, sending out branches at nearly a right angle, and forming a membrane about as loosely interwoven as the fructification of the common *Corticium vagum*. These hyphae range from  $4\frac{1}{2}$  to  $6\ \mu$  in diameter and are neither nodose-septate nor incrustated. In the Porto Rican specimens, which have most of their basidia still swollen with protoplasm and only occasionally bearing spores, and are therefore hardly mature, the hyphae are mostly hyaline and show no tinge of color except in the case of those hyphae next to the substratum, where local thickenings of the fructification occur. In the Ernst collection from Venezuela the hyphae when stripped from the leaf are of a very dilute honey-yellow—the honey-yellow of Ridgway greatly diluted. The hyphae of the specimen from Colombia are sometimes hyaline and sometimes with a slight yellowish tint, being about intermediate between the Ernst collections and those from Porto Rico.

Basidia are scattered along the hyphae at right angles to the surface of the leaf. But few basidia are present in the Ernst specimen, which appears to me to be old, and I did not succeed in finding spores in the few preparations which the bit of material permitted. Miss Wakefield found the spores of this collection to be  $9-13 \times 3\frac{1}{2}-4\ \mu$ . The basidia collapse quickly after spore formation.

Nothing in the nature of appressoria for attachment of the fructification to the leaf could be found; the fructification appears to be anchored along the under side of the leaf by the hyphae from the parasitic intercellular vegetative mycelium,

which pass out to the under side of the leaf and there branch, become interwoven and form the membranous fructification.

The spores are very uniform in size and form, hyaline, even, slightly curved,  $9-13 \times 3\frac{1}{2}-4 \mu$  for all American collections, and were published by von Höhnelt as  $10-12 \times 4-4\frac{1}{2} \mu$  for the Mysore type, and noted by Miss Wakefield as  $10-13 \times 4-5 \mu$  for the latter.

Von Höhnelt described Cooke's type of *Pellicularia koleroga* from Mysore as having "Grundhyphen gerade verlaufend, dünnwandig, meist blaszbräunlich, 6 bis 7  $\mu$  breit, langgliedrig; . . . Zweige zartwandig, hyalin, mit aufeinander fast senkrecht stehenden Abzweigungen versehen." Miss Wakefield has noted as hyaline the hyphae of this specimen which she has drawn.

In the comment following the specific description of *Pellicularia koleroga*, Cooke stated, "threads creeping, branched, septate, interwoven into a subgelatinous pellicle which can be stripped from the leaf when moist." The introduction of the word *subgelatinous* was unfortunate and misleading, for it gave the idea of a fructification of the consistency of a tremellaceous fungus or of a gelatinous lichen. If we turn to *Popular Science Review* 15:164, we see that Cooke was led to assume the presence of a gelatinous medium to account for the fact that organs which he regarded and figured as spores—which we now conclude were the basidia—did not float loose in any case from the hyphae upon which they were borne. In all fungi of gelatinous or tremellaceous consistency which the present writer has studied, the gelatinous substance is due to a gelatinous modification of the outer portion of the cell wall of the hyphae concerned, so that only the lumen of the hypha remained sharply defined when observed with the microscope; the cell walls of the hyphae of the type of *Pellicularia koleroga* in the preparations received from Miss Wakefield are not in the least degree gelatinously modified. However, when, in case of other collections, I moisten the fructification on the leaf and detach it from the surface of the leaf with the point of a scalpel, I do detect in

places from along the very surface of the leaf a very delicate transparent membranous structure suggestive of the hypothallus of such a myxomycete as *Stemonitis* but much more tenuous and delicate. It is quite possible that this pellicle is a portion of the surface of the leaf, for it does not show in all preparations. Fawcett, who had the good fortune to be able to compare with Porto Rican material freshly collected specimens of *Pellicularia koleroga* collected by E. J. Butler at the type locality, Mysore, India, stated that the conclusion by Kuijper that the Porto Rican fungus is not *Pellicularia koleroga*, would seem reasonable if the possession of a gelatinous matrix were necessary to make it that fungus, but that the Mysore specimens agreed in every way with those growing in Porto Rico. In his independent redescription, as a *Corticium*, of Cooke's type of *Pellicularia koleroga*, von Höhnel does not employ the word *subgelatinous*, which everything seems to show should never have been used in connection with the fungus under consideration.

This study of the *Pellicularia* fungus on coffee plants in the tropics of America leads to the conclusion that this fungus is a *Corticium* not specifically distinct from *Corticium koleroga* (Cooke) v. Höhn., and that the description should be broadened slightly to comprehend better the specimens now known from widely separated regions, as follows:

***Corticium koleroga*** (Cooke) v. Höhn. K. Akad. Wiss. Wien Sitzungsber. 119 : 395. 1910.

*Pellicularia koleroga* Cooke, *Grevillea* 4 : 116, 134. 1876; Pop. Sci. Rev. 15 : 164. pl. 135. f. a-c. 1876; Linn. Soc. Bot. Jour. 18 : 461. 1881; Sacc. Syll. Fung. 4 : 149. 1886; Fawcett, G. L., Porto Rico Agr. Exp. Sta. Ann. Rept. 1910 : 35. 1911; Jour. Agr. Res. 2 : 231. text f. 1-3. 1914; Porto Rico Agr. Exp. Sta. Bul. 17 : 8. pl. 1. 1915.—*Erysiphe scandens* Ernst, A., Estudios sobre las Deformaciones, Enfermedades y Enemigos del Arbol de Cafe in Venezuela, 16. pl. f. 5. 1878.

Type: in Kew Herb.

The parasitic vegetative mycelium forms long, slender, mycelial strands of rather uniform diameter, whitish or pallid

at first, finally fuscous, running along the branches and midrib and veins of the leaves, infecting the leaves and ramifying between the cells of the leaf parenchyma, finally emerging at many points on the under side of the leaf to form minute fructifications which give a mottled appearance to the leaf; fructifications soon laterally confluent into a thin, arachnoid, perforate membrane covering the under surface of the leaf between midrib and principal veins, drying pale

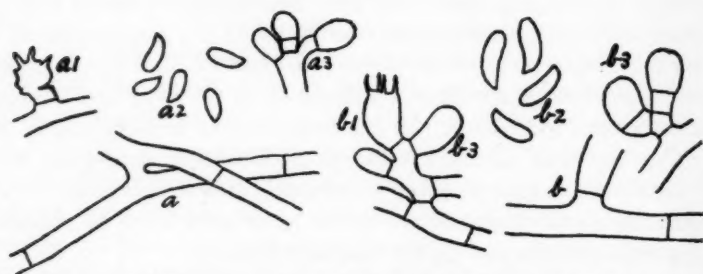


Fig. 1. *C. koleroga*. *a*-*a3*, from sketches by Miss Wakefield of structure of type in Kew Herbarium; magnification not stated but computed from spore dimensions at about 630. *a*, hypha; *a1*, collapsed basidium; *a2*, spores; *a3*, young basidia. *b*-*b3*, from Porto Rican specimen,  $\times 870$ . *b*, hypha; *b1*, basidium; *b2*, spores; *b3*, young basidia.

smoke-gray, separable in small pieces, composed of loosely interwoven, hyaline or slightly colored, thin-walled, even, rigid hyphae  $4\frac{1}{2}$ - $6\ \mu$  in diameter, not nodose-septate, running parallel with the substratum, and about 1-3 hyphae thick, branching at right angles; basidia scattered along the hyphae, simple, ovoid,  $10-12 \times 7-8\ \mu$ , with short sterigmata; spores hyaline, even, flattened or slightly concave on one side,  $10-13 \times 3\frac{1}{2}-5\ \mu$ .

Mycelial strands in the specimens received are 35 cm. long and broken with the branch at the lower end,  $\frac{1}{2}$ -1 mm. in diameter, not swollen into sclerotia; fructifications 9 cm. long, 4 cm. broad,  $30-45\ \mu$  thick, more or less divided by the midrib and principal veins.

Parasitic on branches and leaves of the coffee plant. India, and the Antilles and neighboring regions of South America.

## Specimens examined:

India: Mysore, preparation from the type (in Kew Herb.).

Porto Rico: Mayaguez, *F. L. Stevens*, 9488 (in Stevens Herb. and in Mo. Bot. Gard. Herb., 54510); *H. E. Thomas* (in Mo. Bot. Gard. Herb., 55397).

Colombia: *H. T. Dawe*, fragment (in Mo. Bot. Gard. Herb. from specimen in Kew Herb.).

Venezuela: *A. Ernst*, fragments showing mottled stage and continuous fructification respectively (in Mo. Bot. Gard. Herb. from specimens in Kew Herb., determined by Ernst as Candelillo, *Erysiphe scandens*).

In 1907, Stevens published in Science, p. 724, under the name *Hypochnus ochroleucus* Noack, the preliminary account of a *Corticium* parasitic upon branches and leaves of the apple, pear, and quince, in the southern United States; the detailed, illustrated account of this fungus was published later in *Annales Mycologici* 7: 49-59. 1909. This fungus is closely related in general aspect and morphological structure to *Corticium koleroga* but differs sufficiently in some details in the collections which have come under observation so that Miss Wakefield and Professor Stevens agree with me in regarding it as a distinct species. In transferring *Hypochnus ochroleucus* Noack to *Corticium*, it becomes necessary to give the species a new specific name, because there is already a valid *Corticium ochroleucum* Bres. In order to bring this species in sharper contrast with the preceding, I redescribe *H. ochroleucus* and name it as follows:

***Corticium Stevensii* Burt, n. nom.**

*Hypochnopsis ochroleuca* Noack, Boletim do Instituto Agronomico Sao Paulo em Campiñas 9: 80. 1898.—*Hypochnus ochroleucus* Noack in Sacc. Syll. Fung. 16: 197. 1902; Stevens, Science N. S. 26: 724. 1907; Stevens & Hall, Ann. Myc. 7: 49-59. text f. 1-8. 1909.—Not *Corticium ochroleucum* Bresadola, Fungi Tridentini 2: 58. pl. 167. f. 2. 1892.

Vegetative mycelium forms on the twigs roundish or oblong, chestnut-brown sclerotia 3-4 mm. in diameter, and also

slender mycelial strands white when young, becoming chestnut-brown, running along the twigs and petioles to the leaves and fructifying there; fructifications at first downy and barely visible, soon thickening into a dirty pinkish buff, felty membrane covering the whole under side of the leaf and frequently separable from it as a whole by mere handling; hyphae hyaline or slightly colored, giving their color to the fructifications, even, thin-walled, not incrustated, not nodose-septate,  $4\frac{1}{2}$ – $7\frac{1}{2}$   $\mu$  in diameter; basidia scattered along the hyphae on short lateral branches, simple,  $11 \times 7$ – $8$   $\mu$ , with four short sterigmata; spores hyaline, flattened or slightly concave on one side,  $8$ – $11 \times 3$ – $4$   $\mu$ .

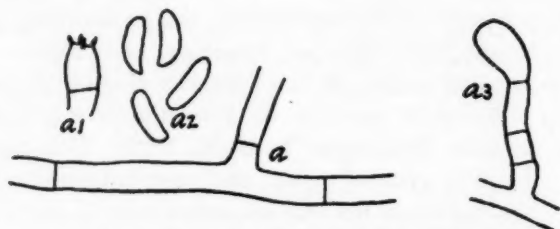


Fig. 2. *C. Stevensii*. From specimen from Trinidad,  $\times 870$ . a, hypha; a1, basidium; a2, spores; a3, young basidium.

Fructification 11 cm. long, 3–4 cm. broad,  $45$ – $60$   $\mu$  thick, unbroken over whole under surface of leaves; sclerotia 3–4 mm. in diameter; mycelial strands  $\frac{1}{2}$ –1 mm. in diameter, many cm. long.

On apple, pear, and quince, in Brazil and southern United States, causing the leaves to dry and fall, and on *Codiaeum* in Trinidad.

This species differs from *Corticium koleroga* by having sclerotia and thicker, darker-colored, and more felted fructifications which are but feebly attached to the leaf and form an unbroken covering over the whole under surface of the leaf from margin to margin. Fruiting specimens of this fungus have been available for study from only two localities, but these specimens agree in the characters stated above.



None of the vertical sections of leaves bearing fructifications of *C. Stevensii* have yet shown vegetative hyphae in the intercellular spaces of the leaves, although I have made several sets of preparations expressly for the demonstration of such hyphae. A set of preparations from the petiole of a pear leaf well-coated with the fungus did not show hyphae in the interior of the petiole. Microscopic characters of *C. Stevensii* and *C. koleroga* are within the limits of fluctuation of a single species. In connection with the collections on *Codiaeum* Dr. Rorer wrote, "This thread blight occurs here in the damp valleys every year and takes quite a toll of crotons, nutmegs, and many decorative plants, even roses."

Specimens examined:

North Carolina: Horseshoe, *J. G. Hall*, comm. by F. L. Stevens, sclerotial stage on pear twigs; Mt. Airy, *F. C. Reimer*, comm. by F. L. Stevens, fertile stage on pear leaves.

Georgia: *A. L. Quaintance*, comm. by F. S. Earle, sclerotial stage on apple twigs.

Florida: *C. G. Lloyd*, sclerotial stage on pear twigs.

Texas: Dickson, *F. W. Mally*, comm. by U. S. Dept. of Agr., sclerotial stage on pear twigs.

Trinidad: Diego Martei, *J. B. Rorer*, fertile stage on leaves of *Codiaeum variegatum* (in Mo. Bot. Gard. Herb., 44771); Petit Valley, *J. B. Rorer*, sclerotial and fruiting stages on leafy twigs of *Codiaeum variegatum* (in Mo. Bot. Gard. Herb., 11960, 19786, 19810, and 20062).

*Corticium vagum* Berk. & Curtis is another parasitic *Corticium*, which belongs in the section with the preceding species by reason of the structure of its fructification. In contrast with the mycelium and sclerotia upon stems of the portions of the host above ground in the preceding species, *C. vagum* has its mycelium saprophytic in the soil and becoming parasitic and sometimes forming sclerotia on subterranean portions of host plants, such as roots or underground stems,—presumably an adaptation to the climatic con-



ditions of the region in which this species lives. The parasitic mycelial stage of *C. vagum* is *Rhizoctonia Solani* Kühn, for full accounts of which and for the literature, reference may be made to the papers by Duggar in Ann. Mo. Bot. Gard. 2: 424-458. 1915, and Peltier, Univ. of Ill. Agr. Exp. Sta. Bul. 189: 283-390. 1916. *Corticium vagum* is known to the writer by fruiting specimens ranging in North America from New Brunswick to southern United States and from the Atlantic to the Pacific, and in Europe by specimens from Sweden and Russian Poland. *Rhizoctonia Solani* has been reported from regions, additional to the above, of the West Indies, India, and Australia. *Corticium vagum* is remarkable, not only by the ability of its vegetative mycelium to live as a saprophyte in soil and wood and as a parasite in living plant tissues, but it may come to the surface and fruit on each of these substrata—very commonly indeed on old wood and bark lying on the ground, more rarely on the small stems of potatoes, tomatoes, rhubarb, radishes, beans, *Amaranthus*, *Plantago*, etc., just above the surface of the ground. I have received only one specimen in which the fructifications were directly on the surface of the ground itself, but the fructification is so inconspicuous when on the ground that it may be easily overlooked. The wide range as to substratum of *C. vagum* has led to its having been described in Europe as *Hypochnus Solani* when collected on potato stems and as *Corticium botryosum* when on old wood. The synonymy and description follow:

*Corticium vagum* Berk. & Curtis, Grevillea 1: 179. 1873; Sacc. Syll. Fung. 6: 616. 1888; Massee, Linn. Soc. Bot. Jour. 27: 148. 1890; Duggar, Mo. Bot. Gard. Ann. 2: 445. 1915; Peltier, Univ. of Ill. Agr. Exp. Sta. Bul. 189: 285. 1915.

*Corticium vagum* Berk. & Curtis var. *Solani* Burt in Rolfs, Science N. S. 18: 729. 1903; Colo. Agr. Exp. Sta. Bul. 91: 1-20. pl. 1-5. 1904.—*Hypochnus Solani* Prill. & Del. Soc. Myc. Fr. Bul. 7: 220. text f. 1891; Sacc. Syll. Fung. 11: 130. 1895.—*Corticium Solani* Prill. & Del. in Bourd. & Galz. Soc. Myc. Fr. Bul. 27: 248. 1911.—*Corticium botryosum* Bresa-

dola, Ann. Myc. 1 : 99. 1903; Sacc. Syll. Fung. 17 : 173. 1905; Bourd. & Galz. Soc. Myc. Fr. Bul. 27 : 248. 1911.—*Rhizoctonia Solani* Kühn, Krankheiten d. Kulturgewächse, 224. 1858; Duggar, Mo. Bot. Gard. Ann. 2 : 424. 1915.

Type: in Kew Herb. and in Curtis Herb.

Vegetative mycelium saprophytic in the soil and in wood in contact with the ground, and parasitic as the *Rhizoctonia Solani* stage in underground portions of various plants and forming at their surface underground minute sclerotia; fructification a thin, arachnoid, perforate membrane more or

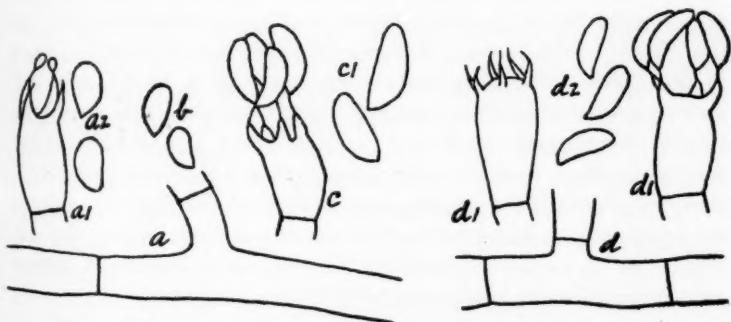


Fig. 3. *C. vagum*,  $\times 870$ . *a-a2*, from specimen on potato in Colorado. *a*, hypha; *a1*, basidium; *a2*, spores. *b*, spores of specimen on *Plantago* in Illinois. *c-c1*, from specimen on earth in Massachusetts. *c*, basidium; *c1*, spores. *d-d2*, from specimen on wood in British Columbia. *d*, hypha; *d1*, basidia; *d2*, spores.

less separable, pale olive-buff to cream color; in structure 60–100  $\mu$  thick, composed of a few loosely interwoven hyphae running along the substratum and sending out short branches which bear the basidia; hyphae in contact with substratum may be slightly brownish, hyaline elsewhere, not incrustated, not nodose-septate, up to 6–10  $\mu$  in diameter, with branches smaller; basidia not forming a compact hymenium, 10–20  $\times$  7½–11  $\mu$ , with 4–6 sterigmata 6–10  $\mu$  long and more or less swollen towards the basidium; spores hyaline, even, flattened on one side, 8–14  $\times$  4–6  $\mu$ .

Fructifications 5–15 cm. long on logs, 5–10 cm. broad; in a collar 1–10 cm. long, sheathing the base of living stems.

On bare earth, wood and bark lying on the ground, and on living stems of potatoes, beans, rhubarb, horseradish, tomatoes, *Amaranthus*, etc., at or near the ground. New Brunswick to Florida and westward to Vancouver and Washington, in West Indies, Europe, India, and Australia. Common.

*Corticium vagum* differs from *C. koleroga* and *C. Stevensii* in having its mycelium and sclerotia subterranean when parasitic, in having its fructifications at the surface of the ground or merely sheathing small herbaceous stems for only a few centimeters up from the ground and never spreading out on the under side of broad leaves at a considerable distance above ground, by having larger hyphae, larger basidia, and the basidia with larger sterigmata which are more thickened in the lower portion and sometimes six to a basidium; the spores are somewhat larger in *C. vagum* also. The examination of the large amount of *C. vagum* which has come to hand does not afford ground for regarding the collar-like fructifications on small living herbaceous stems as worthy of varietal separation. As common as this species now is in the United States, it is rather surprising that a collection of it under some name has not been found in Herb. Schweinitz.

Specimens examined:

Exsiccati: Ellis, N. Am. Fungi, 330; Ravenel, Fungi Am., 132, 577—the latter under the name *Zygodesmus pannosus*.

Sweden: Stockholm, L. Romell, 204.

Russian Poland: Eichler, comm. by Bresadola, portion of type of *Corticium botryosum* Bres.

New Brunswick: Campobello, W. G. Farlow, 3.

Canada: J. Macoun, 2, 84, 340.

Ontario: Ottawa, J. Macoun, 327.

Massachusetts: Brookline, G. R. Lyman, 180; Magnolia, W. G. Farlow.

New York: Albany, H. D. House & J. Rubinger (in Mo. Bot. Gard. Herb., 8734); East Galway, E. A. Burt, two collections; Ithaca, Van Hook, comm. by G. F. Atkinson, 8092; Karner, H. D. House, 14.162, and three other collections (in N. Y. State Herb. and Mo. Bot. Gard. Herb., 44709,

- 54349, 55199, 55203); Tripoli, *S. H. Burnham*, 13, in part (in *Mo. Bot. Gard. Herb.*, 54506).
- New Jersey: Belleplain, *C. L. Shear*, 1244; Newfield, *J. B. Ellis*, in *Ellis*, *N. Am. Fungi*, 330.
- Pennsylvania: Carbondale, *E. A. Burt*; Trexlertown, *W. Herbst*, 95.
- Maryland: Takoma Park, *C. L. Shear*, 1164, 1334.
- District of Columbia: Takoma Park, *C. L. Shear*, 965, 1041 (the former in *Mo. Bot. Gard. Herb.* also).
- South Carolina: Curtis Herb., 3240, type (in *Kew Herb.* and in *Curtis Herb.*); Aiken, *H. W. Ravenel*, in *Ravenel*, *Fungi Am.*, 132, 577.
- Alabama: Montgomery, *R. P. Burke*, 170 (in *Mo. Bot. Gard. Herb.*, 43162).
- West Virginia: Paw Paw, *C. L. Shear*, 1171.
- Ohio: Cincinnati, *C. G. Lloyd*, 4508.
- Illinois: Urbana, *G. L. Peltier*, fourteen collections, on living stems of beans, carrot, tomato, radish, rhubarb, horseradish, potato, winter vetch, spinach, *Amaranthus*, *Campanula*, and *Plantago major* (in *Mo. Bot. Gard. Herb.*, 6264, 8761-8765, 8816, 43836, 44677-44682).
- Montana: Evaro, *J. R. Weir*, 434 (in *Mo. Bot. Gard. Herb.*, 17725).
- Idaho: Priest River, *J. R. Weir*, 140, 89 in part (*Mo. Bot. Gard. Herb.*, 8197, 11349).
- Colorado: Fort Worth, *F. M. Rolfs*, two collections, on living stems of potatoes.
- British Columbia: Sidney, *J. Macoun*, 4, 20, 83, 85, 87, 26, 154 (in *Mo. Bot. Gard. Herb.*, 5764, 5735, 7068, 7024, 7833, 55347, 55350, respectively) and 39a, 151, 172 (in *Macoun Herb.*); Vancouver Island, *J. Macoun*, V89, V90, V151, V154, V172 (in *Mo. Bot. Gard. Herb.*, 22815, 22927, 20357, 20507, 20728, respectively).
- Washington: Bingen, *W. N. Suksdorf*, 846, 852, 863.

The term "thread blight" has been frequently used in plant pathology with reference to tropical fungi which ascend stems by filamentous, mycelial strands and fructify on the leaves, as in the case of *Corticium koleroga*. Such aërial,

mycelial strands are an adaptation to tropical climate for dispersal, apparently common to many species of fungi of various genera and families. In addition to the specimens of *C. koleroga* and *C. Stevensii*, cited in the earlier pages of this paper, I have seen collections by Mr. J. A. Stevenson, 6498, 6748, 6748a, on *Casearia sylvestris* and *Hippocratea volubilia* from Rio Piedras and Bayamon, Porto Rico, which show soft, white, mycelial strands running along the stems of the host plant to the leaves and not yet fruiting. Dr. F. L. Stevens, 7469, on *Mayepea domingensis*, from Mayaguez Mesa, Porto Rico, has a specimen, with fructifications still too immature for determination, which has spread by an effused mycelium rather than narrow strands for distances of three to four feet along the stems and extends out to leaves along the way. On the living leaves of *Nephrolepis*, in Porto Rico, Dr. Stevens has a very interesting collection, No. 4380, which has the configuration of a resupinate species of *Hydnum* but has not yet formed basidia and spores. Dr. J. B. Rorer has sent to me from Trinidad photographs of the mycelial strands of the horse-hair blight on the stems of cacao, which seem to be white, cylindric, and compact; he notes that their fructification is usually a polypore.

It is evident that many kinds of fungi in the tropics have the curious "thread blight" habit of growth. One so fortunately placed as to be able to collect such fungi where growing could make sure that the fructifications were mature and of value for taxonomic study by making a spore collection on a glass microscope slide from the fresh specimen.

## GAUTIERIA IN NORTH AMERICA<sup>1</sup>

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### GAUTIERIA

*Gautieria* Vittadini, Monogr. Tuberac. 25-27. 1831; Klotzsch in Dietr. Fl. Boruss. (Fl. Königr. Preuss.) 7: No. 764. pl. 464. 1839; Tulasne, Fung. Hypog. 62-63. 1851; Zobel in Corda, Icon. Fung. 6: 33-34. 1854; Winter in Rabenh. Krypt.-Fl. Deutschl. ed. 2, 1: 873-874. 1884; DeToni in Sacc. Syll. Fung. 7: 177-179. 1888; Hesse, Hypog. Deutschl. 1: 105-110. 1891. —*Gautiera* Endlicher, Gen. Pl. 30. 1836-1840; Corda, Anleit. z. Stud. Myc. 114. 1842; Icon. Fung. 5: 28. 1842; Rabenhorst, Deutschl. Krypt.-Fl. 1: 252. 1844; Fries, Summa Veg. Scand. 435. 1849. —Not *Gautiera* Rafinesque, Med. Fl. 1: 202. 1828.

The type species of the genus is *Gautieria morchelliformis* Vittadini.

Fructifications globose to somewhat irregular, with a simple or branched rhizomorph; columella variable in size and shape; peridium thin, fugacious; gleba white at first, becoming colored by the masses of spores; cavities variable in size, often elongated, labyrinthiform; septa homogeneous, composed of closely interwoven, parallel hyphae, not conspicuously gelatinized at maturity; basidia clavate, usually 2-spored, with long filiform sterigmata; spores ellipsoidal to citriform, unicellular, with longitudinal thickenings of the cell wall.

Although *Gautieria* was originally described as lacking a peridium, it has been reported<sup>2</sup> to have one in its early stages of development. For this reason we are inclined to consider *Chamonixia* Rolland as synonymous with *Gautieria*, but since

<sup>1</sup> Issued May 24, 1918.

<sup>2</sup> Corda, A. C. J. Icones Fungorum 6: 33. 1854; Hesse, R. Die Hypogaeen Deutschlands 1: see p. 106. 1891; Fitzpatrick, H. M. A comparative study of the development of the fruit-body in *Phallo-gaster*, *Hysterangium*, and *Gautieria*. Ann. Myc. 11: 119-149. pl. 4-7. f. 1-4. 1913.



we have not studied the type material, we prefer not to change the name.

Although we have had the opportunity to study a few specimens which were put up in alcohol, our descriptions are based on dry herbarium specimens, as is also our key. As a standard for color descriptions we have used Ridgway, 'Color Standards and Nomenclature,' Washington, D. C., 1912. As to the citation of specimens, the data given is that received with the specimens. The location of all specimens is designated by giving in parenthesis the name of the herbarium preceded by "in."

We are indebted to the Missouri Botanical Garden for the use of the library and herbarium; to Dr. E. A. Burt for helpful suggestions; to Dr. LeRoy Abrams for the privilege of studying Harkness's type; to Mr. S. H. Burnham for his collections; to Dr. H. M. Fitzpatrick for specimens from New York; to Dr. N. L. Gardner for his collections; to Mr. C. G. Lloyd for the privileges of his herbarium; to Dr. W. A. Murrill for collections from the New York Botanical Garden Herbarium; to Mrs. F. W. Patterson for specimens from the Pathological Collections, Bureau of Plant Industry, United States Department of Agriculture; and to Dr. J. R. Weir for specimens from Idaho.

#### KEY TO THE NORTH AMERICAN SPECIES

1. Spores mostly more than  $14\ \mu$  long..... 2
1. Spores mostly shorter than  $14\ \mu$ ..... 4
  2. Superficial cavities large and prominent..... *G. morchelliformis* (p. 134)
  2. Superficial cavities small..... 3
3. Septa wholly composed of slender hyphae..... *G. graveolens* (p. 136)
3. Septa composed of a pseudo-parenchyma; the subhymenium of large, angular cells..... *G. Trabuti* (p. 137)
4. Slate-colored to nearly black; columella long; cystidia present..... *G. plumbea* (p. 138)
4. Brownish; columella short; cystidia absent..... *G. monticola* (p. 139)

1. *Gautieria morchelliformis*<sup>1</sup> Vittadini, Monogr. Tuberae. 26. 1831; Klotzsch in Dietr. Fl. Boruss. (Fl. Königr. Preuss.) 7: No. 764. 1839, in part; Tulasne, Fung. Hypog. 62. 1851; Corda, Icon. Fung. 6: 34. 1854; Winter in Rabenh. Krypt.-Fl.

<sup>1</sup> Originally spelled *morchellaeformis*.



Deutschl. ed. 2, 1: 873. 1884; DeToni in Sacc. Syll. Fung. 7: 177-178. 1888; Hesse, Hypog. Deutschl. 1: 109-110. 1891.

*Gautieria morillaeformis* Quelet, Ench. Fung. 250. 1886.—*Gautieria villosa* Quelet, Soc. Bot. Fr. Bull. 25: 290. 1878 (often cited as Champ. du Jura et des Vosges, Suppl. 6: 290. 1878); Ench. Fung. 250. 1886; Winter in Rabenh. Krypt.-Fl. Deutschl. ed. 2, 1: 873. 1884; DeToni in Sacc. Syll. Fung. 7: 178. 1888.

Illustrations: Bucholtz, Ann. Myc. 1: pl. 5. f. 14; Corda, Icon. Fung. 6: pl. 7. f. 62; Bail in Nees v. Esenbeck, Th. F. L. & Henry, A. Syst. d. Pilze 2: pl. 27. f. 1-4; Vittadini, Monogr. Tuberac. pl. 3. f. 6; Klotzsch in Dietr. Fl. Boruss. (Fl. Königr. Preuss.) 7: pl. 764.

Type: location unknown to us.

Fructifications globose to oblong, 1-3 cm. in diameter, with a basal stalk-like rhizomorph, usually much branched; columella rudimentary, merely a subglobose summit of the rhizomorph; peridium thin in early stages, quickly evanescent; gleba ochraceous-tawny to hazel; cavities 1-6 mm. in diameter, subglobose to irregular; septa white when broken, hyaline to cream-colored under the microscope, composed of a stupose mat of hyphae, about 75  $\mu$  broad; basidia about as large as the spores, hyaline, granular, 2-3-spored; sterigmata filiform, as long as the spores; cystidia in the upper cavities of the fructification, not prominent; paraphyses clavate, septate, hyaline; spores fusiform to citriform, ochraceous, longitudinally striate, with 8-10 usually smooth striations, 1-2-guttulate, pedicellate, 12-24 $\times$ 8-12.5  $\mu$ .

In clay soil. Europe and United States. Spring and summer.

We have placed *Gautieria villosa* Quelet in synonymy, for we have been unable to distinguish it from *G. morchelliformis*, and Quelet himself later (1886) believed them to be the same species. Winter studied the type, as well as Bresadola's collection, which we have studied, and he believes they are synonymous. The villous character to which Quelet had reference might have been the granular appearance often produced by an accumulation of spores on the surface of the gleba.

## Specimens examined:

Exsiccati: Roumeguère, Fung. Gall. Exsicc., 2218, under the name *G. villosa*.

Austria: Bohemia, Tabor, *F. Bubak* (in Lloyd Mus., 05860); Tyrol, near Magras, *G. Bresadola*, in Roumeguère, Fung. Gall. Exsicc., 2218 (in N. Y. Bot. Gard. Herb.).

France: Jura, *N. Patouillard* (in Lloyd Mus., 08+53).

New York: Washington Co., Hudson Falls, *S. H. Burnham* (in Burnham Herb., Dodge Herb., 850, and Zeller Herb., 1449).

California: Claremont, *L. M. Clency* (in Pomona Coll. Herb., 1759, and in Lloyd Mus., 1759); San Jose, *H. E. Parks* (Univ. Cal. Herb., 541, Zeller Herb., 1457, and Dodge Herb., 860).

2. *Gautieria graveolens* Vittadini, Monogr. Tuberac. 27. 1831; Tulasne, Fung. Hypog. 63. 1851; Corda, Icon. Fung. 6: 34. 1854; Winter in Rabenh. Krypt.-Fl. Deutschl. ed. 2. 1: 873-874. 1884; DeToni in Sacc. Syll. Fung. 7: 178. 1888; Quelet, Ench. Fung. 250. 1886; Hesse, Hypog. Deutschl. 1: 106-108. 1891.

*Gautieria graveolens*? Chatin, La Truffe, 82-83. 1892.—*Gautieria graveolens* var. *mexicana* Fischer in Engler & Prantl, Die Nat. Pflanzenfam. I. 1<sup>\*\*</sup>: 305. 1899.

Illustrations: Bucholtz, Ann. Myc. 1: pl. 5. f. 14; Chatin, La Truffe, pl. 15. f. 4; Corda, Icon. Fung. 6: pl. 7. f. 63; Fischer in Engler & Prantl, Die Nat. Pflanzenfam. I. 1<sup>\*\*</sup>: 304; Fitzpatrick, Ann. Myc. 11: pl. 4. f. 11, pl. 7. f. 30-37; Hesse, Hypog. Deutschl. 1: pl. 2. f. 5-9, pl. 7. f. 4-6; Vittadini, Monogr. Tuberac. pl. 4. f. 3.

Type: in Saccardo Herb. at Padua.

Fructifications globose, 1-2 cm. in diameter, light ochraceous-buff to Prout's brown; stipe slender and fragile, up to 1 cm. long, 1 mm. thick; columella frequently reaching the center of the fructification, forking; odor very strong, suggestive of decaying onions; peridium thin, composed of delicate, thin-walled, loosely woven hyphae, soon rupturing and disappearing; gleba ochraceous-tawny to cinnamon-brown; cavities globose or elongated, minute, empty; septa 40-80  $\mu$

thick, composed of small hyphae, compact; cystidia clavate to subfusiform, hyaline, often obscured by the spores; paraphyses linear, septate; basidia broadly clavate, 2-spored,  $12-16 \times 8-9 \mu$ , with long filiform sterigmata; spores ochraceous-tawny, usually with 10 prominent striations, the latter smooth or nearly so, apex rounded, base pedicellate,  $18-19 \times 11-12 \mu$ , often with a large oil globule.

Deeply buried under leaf mould. Europe and North America. Summer.

Specimens examined:

Exsiccati: Saccardo, D. Mycoth. Ital., 427; de Thümen, Mycoth. Univ., 12.

Austria: Bohemia, Vysoky, Chluniec ad Selcany, *F. Bubak* (in Lloyd Mus., 058590); Tyrol, Cavelonte, *G. Bresadola*, in D. Saccardo, Mycoth. Ital., 427 (in U. S. Dept. Agr., Bur. Pl. Ind. Path. Coll.).

Germany: Saxony, Eisleben, *J. Kunze* (collections in Lloyd Mus., 05916, and in Mo. Bot. Gard. Herb., 5637); *G. Winter*, in de Thümen, Mycoth. Univ., 12 (in Lloyd Mus., Mo. Bot. Gard. Herb., and U. S. Dept. Agr., Bur. Pl. Ind. Path. Coll.).

New York: Ithaca, *H. M. Fitzpatrick* (in N. Y. Coll. Agr. at Cornell Univ., Dept. Pl. Path. Herb., 8450).

3. *Gautieria Trabuti* (Chatin) Patouillard, Soc. Myc. Fr. Bull. 13: 203-204. 1897.

*Hymenogaster Trabuti* Chatin, Soc. Bot. Fr. Bull. 38: 64. 1891.

Illustrations: Patouillard, Soc. Myc. Fr. Bull. 13: pl. 13. f. 2.

Type: probably in Patouillard Herb. but unknown to us.

Fructifications subglobose, about 3 cm. in diameter, surface convoluted, Verona brown in preserved material; stipe slightly developed, arising from very fine, brown rhizomorphs of septate hyphae with prominent clamp connections; columella dendroid; peridium made up of loosely woven, large, septate hyphae with swollen cells, soon evanescent; gleba Brussels-brown; cavities irregular, empty; septa hyaline,  $180-240 \mu$  thick, composed of a pseudo-parenchyma of

large, subglobose to polygonal cells; cystidia subcylindric, thin-walled,  $8\ \mu$  in diameter; paraphyses filiform, septate, guttulate,  $3-4\ \mu$  in diameter; basidia hyaline, many-guttulate,  $25-30 \times 10-16\ \mu$ , obovate to clavate, mostly 4-spored; sterigmata stout,  $5-8\ \mu$  long; spores acrogenous, 1-3-guttulate, cinnamon to cinnamon-buff, short-pedicellate, globose when young, becoming ellipsoidal,  $16-21 \times 8-10\ \mu$ , with 5-9 striations usually prominently warted.

Deeply buried in forests. Algeria and California. April. Specimens examined:

California: San Jose, *H. E. Parks* (in Univ. Cal. Herb., 493, Zeller Herb., 1455, and Dodge Herb., 858).

#### 4. *Gautieria plumbea* Zeller & Dodge, sp. nov.

Fructificationes ovatae, 4 cm. diametro metiens, cordis effigies, superficie convoluta, "light brownish olive" vel "mummy-brown" (Ridgway); stipes 2 mm. crassitudine; columella ramosa, fere fructificationem percurrens, translucens; gleba "plumbeous-black" vel "slaty" (Ridgway) servata, "fuscous-black" (Ridgway) siccata, gelatinosa; locelli irregulares, vacui; septa hyalina, circa  $300\ \mu$  crassitudine, hyphis gelatinosis confecta; stratum subhymeniale pseudo-parenchymate, id est, cellulis polygoniis confectum; cystidia magna,  $52-61 \times 25-35\ \mu$ , hyalina, granulate guttulata, obovata, saepe subapiculata; paraphyses anguste clavatae, granulate guttulae, septatae,  $4-5\ \mu$  crassitudine, partim apice bullatae, partim filiformes; basidia hyalina, granulate guttulata, clavata,  $20-26 \times 9-10\ \mu$ , mono- vel tetraspora, sterigmatibus brevibus; sporae  $11-16 \times 6.5-8\ \mu$ , breviter pedicellatae, longitudinaliter striatae, striis 7-10, sinuosis, "English red" vel "burnt sienna" (Ridgway); sporae iuniores ovatae vel ellipsoideae, breviter pedicellatae, leves, deinde striatae.

Habitat in terra in pinetis. Idaho. Autumno.

Type: in Weir Herb., Zeller Herb., and Dodge Herb.

Fructifications ovate, 4 cm. in diameter, heart-shaped, surface convoluted, light brownish olive to mummy-brown; stipe 2 mm. thick; columella branched, trunk reaching almost to the top of the fructification, translucent; gleba plumbeous-black, slaty when in preservative, drying fuscous-black, gelatinous; cavities irregular, empty; septa hyaline, about  $300\ \mu$  thick, composed of gelatinized hyphae; subhymenial layer a pseudo-parenchyma of large angular cells; cystidia large,  $52-61 \times 25-35\ \mu$ , hyaline, granularly guttulate, obovate, often somewhat apiculate; paraphyses narrowly clavate, hyaline,

granularly guttulate, septate, 4–5  $\mu$  broad, some knobbed at the tip, some filiform; basidia hyaline, granularly guttulate, clavate, 20–26 $\times$ 9–10  $\mu$ , 1–4-spored; sterigmata less than half the length of the spores; spores 11–16 $\times$ 6.5–8  $\mu$ , short-pedicellate, longitudinally striate, with 7–10 wavy striations, from English red to burnt sienna; young spores ovate to ellipsoidal, short-pedicellate, smooth, then striate.

Under conifers. Idaho. September to October.

The color of the gleba and the prominence of the columella make this species distinct from all others. It is most closely allied with *G. Trabuti* in tramal characters, but the spores are more nearly the size of *G. monticola* than those of any other species.

Specimens examined:

Idaho: Priest River, *J. R. Weir*, type (in Weir Herb., in Zeller Herb., 1458, and Dodge Herb., 859).

5. *Gautieria monticola* Harkness, Cal. Acad. Sci. Bull. 1: 30. 1884; DeToni in Sacc. Syll. Fung. 7: 178–179. 1888.

*Hymenogaster monticolus* Harkness, Cal. Acad. Sci. Proc. Bot. III. 1: 249. 1899.

Type: in Dudley Herb. at Leland Stanford Jr. Univ. and in N. Y. Bot. Gard. Herb.

Fructifications irregularly lobed, nearly plane above and below, 10 cm. in diameter (Harkness), about 3 cm. thick, Dresden brown to mummy-brown; stipe short, slender, darker; columella short, branching, concolorous with the stipe; peridium evanescent; gleba ochraceous-tawny, grayish where cut, due to the thick, hyaline septa; cavities irregular, more or less anastomosing, nearly filled with spores when dry; septa 140–400  $\mu$  thick, hyaline, composed of more or less gelatinized hyphae, mostly parallel with the hymenial surface; cystidia none; basidia arising from erect, septate hyphae, hyaline, 16 $\times$ 6–7  $\mu$ , ovate, mostly 2-spored; sterigmata filiform, 7–10  $\mu$  long; spores acrogenous, 1–several-guttulate, ochraceous-tawny, short-pedicellate, ellipsoidal to obovate, 9–13 $\times$ 6.5–8  $\mu$ , with 7–10 longitudinal or oblique striations sometimes slightly warted.

On the ground under conifers. California. July.



## Specimens examined:

California: Mariposa County, Big Meadow, *W. A. Setchell* (in Univ. Cal. Herb., 542, Zeller Herb., 1454, and Dodge Herb., 857); Big Tree Grove, *H. W. Harkness*, 113 [3543], type (in Dudley Herb. at Leland Stanford Jr. Univ. and N. Y. Bot. Gard. Herb.).

## EXTRA-LIMITAL AND DOUBTFUL SPECIES

The following are descriptions of species not yet found in North America, but are included in order to assist in referring material to them in case they should be discovered later, as individual species are found to have a wide range. The descriptions are either copies or translations of the original descriptions, since no material here has been studied. Such notes are appended to them as seemed justified by a careful study of the original text and illustrations.

1. *Chamonixia caespitosa* Rolland, Soc. Myc. Fr. Bull. 15: 76, 1899; Saccardo and Sydow in Sacc. Syll. Fung. 16: 251, 1902.

Illustrations: Rolland, Soc. Myc. Fr. Bull. 15: pl. 6. f. 3.

Type: location unknown to us.

Globose mass of several fructifications, pressed against each other like the carpels of an orange but easily separable, covered by a membranous peridium, floccose-silky, white, bluing rapidly to the touch. The peridium surrounds the outside of the fructification but not where the several fructifications come together. Gleba fleshy, flesh-colored, of round or oval cavities, no sterile portions; basidia 2-spored; spores brown, ellipsoidal, longitudinally striate,  $20 \times 12 \mu$ , guttulate. Floccose, radicating mycelium below, odorless. In cross-section the peridium shows distinctly, being blue where cut.

Among mosses clothing the base of an old tree (*Abies excelsa*), Bois du Bouchet near Chamonix, Sept. 15, 1898.

—Rolland.

This species seems to be a *Gautieria*, although we prefer not to make the transfer until we have seen the type. It seems quite possible that the columella is more strongly developed in this species, running all the way through the fructification and dividing the gleba into several distinct portions, as there is a tendency to do in *G. plumbea*. The spore color seems to relate it to the latter species if the colors of the illustration are to be trusted.

2. *Gautieria Otthii* Trog, Naturforsch. Ges. Bern Mitt. 1857: 43. 1857 (in Nos. 388-390) [sometimes cited as Verzeichniss schweiz. Schwämme Nachtrag 3: 43. 1857]; Saccardo & Sydow in Sacc. Syll. Fung. 14: 268. 1899.

Fructification globose, 1-1¼ inch long, slightly narrower, with a "rootlet" at the base connected with a white columella. The long, somewhat winding cavities are numerous and small, visible with a weak lens, within larger but uniformly distributed, and as there is no peridium, the cavities are visible on the upper surface, of the same form as those within. They are wholly formed by the hymenium which bears striped, egg-shaped spores on short basidia. Spores brown and filled with granules. Odor weak, unpleasant.

Hardlisberg, Switzerland. *Oth.*

—Trog.

There seems to be nothing in the above description to differentiate *G. Otthii* from *G. graveolens* Vitt. As both common species of *Gautieria* have been reported from Switzerland and as Trog reports *G. morchelliformis* Vitt., it seems highly probable that this species should be reduced to synonymy, but it seems unwise to do so before studying type material or material from the type locality.

3. *Gautieria Drummondi* Cooke, Handbook of Australian Fungi, 247. 1892.

Illustration: Cooke, Handbook of Australian Fungi, pl. 15. f. 130.

"Subglobose, small; cells sinuous; spores ellipsoid, with large nucleus, 14-15×8  $\mu$ , hyaline.

"In the soil. W. Australia."

—Cooke.

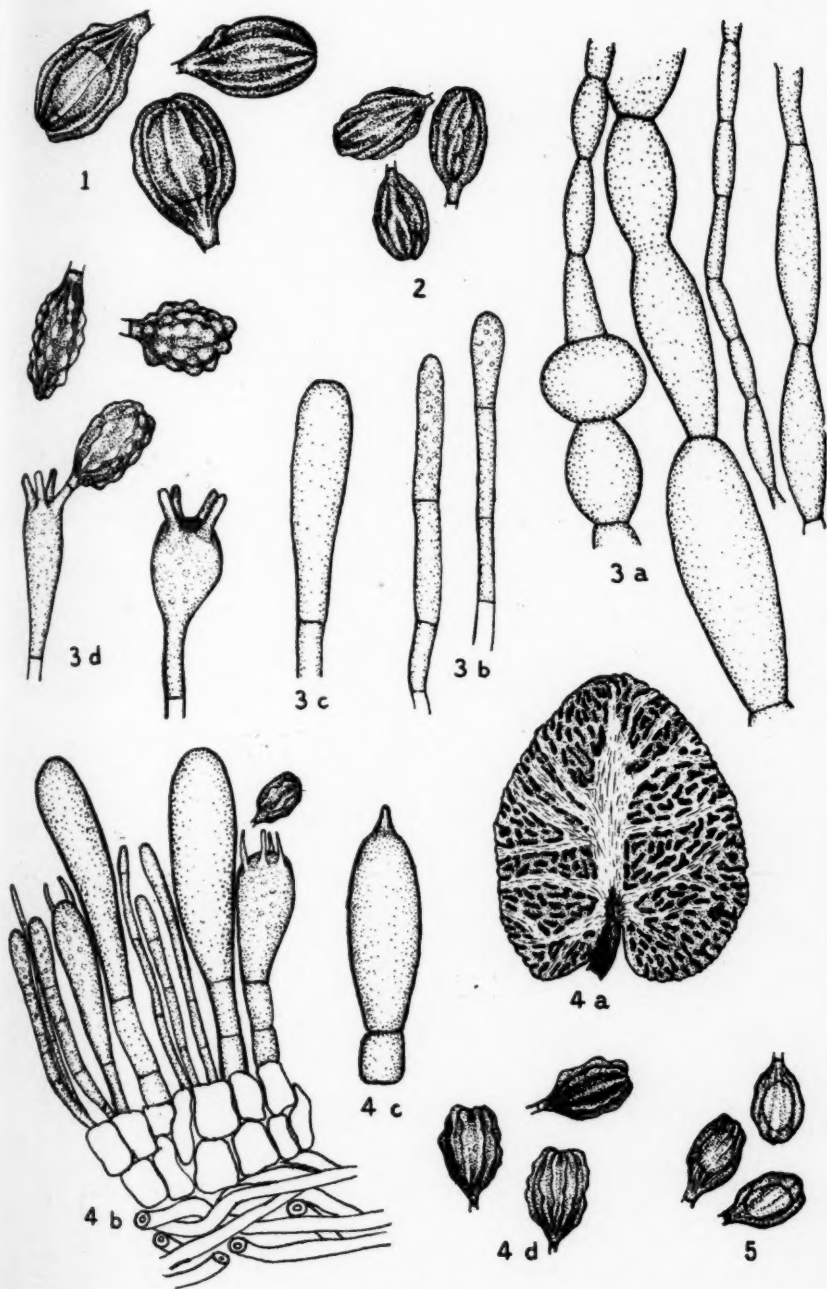
Cooke described this form from a specimen (No. 4446 in Berkeley's herbarium) in fragmentary condition. If Cooke's drawings are at all reliable, this plant is a *Rhizopogon* and would probably fall into synonymy in that genus. The spore measurements are rather larger than in many species of *Rhizopogon*, but much smaller than any in *Gautieria* except *G. monticola* and *G. plumbea*. Only a study of the type material can decide the position of this species. The description would fit either genus.



## EXPLANATION OF PLATE

## PLATE 9

- Fig. 1. Spores of *Gautieria morchelliformis*;  $\times 1000$ .  
Fig. 2. Spores of *G. graveolens*;  $\times 1000$ .  
Fig. 3a. Showing the forms of hyphae in the evanescent peridium of *G. Trabuti*;  $\times 625$ .  
Fig. 3b. The guttulate paraphyses of *G. Trabuti*;  $\times 1000$ .  
Fig. 3c. A cystidium of *G. Trabuti*;  $\times 1000$ .  
Fig. 3d. Showing basidia and spores of *G. Trabuti*, the ribs of the spores being usually warted;  $\times 1000$ .  
Fig. 4a. A vertical median section of a fructification of *G. plumbea*, showing the stalk, branching columella and gleba; nat. size.  
Fig. 4b. Section of the hymenium of *G. plumbea*, showing gelatinized tramal hyphae, angular cells of the subhymenium, paraphyses, cystidia, and basidia;  $\times 625$ .  
Fig. 4c. Showing a cystidium with apiculate tip;  $\times 625$ .  
Fig. 4d. Spores of *G. plumbea*;  $\times 1000$ .  
Fig. 5. Spores of *G. monticola*;  $\times 1000$ .



ZELLER AND DODGE — GAUTIERIA



## NOTES ON CERTAIN CRUCIFERAE

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### SYNTHLIPSIS Gray

Pods oblong, strongly flattened contrary to the septum; valves sharply carinate, distinctly margined at the apex; areolae of septum not at all tortuous; ovules 6-12 in each cell; seeds with a mucilaginous testa whose cells emit spiral threads when wet.

*S. Greggii* Gray, Mem. Am. Acad. N. S. [Pl. Fendl.] 4: 116. 1849.

*Synthlipsis*, as originally limited, remains monotypic and quite distinct from *Lesquerella* by reason of the carinate valves, the different septum, and the mucilaginous seed coat. Several other species have from time to time been referred to this genus because of their flattened pods. In all other ways, however, these agree with *Lesquerella* and in that genus they must be placed. One species seems even to have been described and maintained under two names—*S. Berlandieri* Gray and *Lesquerella lasiocarpa* (Hook.) Wats.

### PHYSARIA Gray

A complete revision of this genus is in course of preparation, but until such time as that may be completed it was thought the following synopsis would be useful in the determination of exsiccatae.

#### KEY TO THE SPECIES AND VARIETIES

- A. Mature pods globose-inflated, not strongly flattened laterally.
  - a. Shoulders of upper sinus (of pods) rounded.
    - a. All the stems lateral; pods usually erect.
      - I. Basal leaves obtuse; blade usually circular in outline.
        - 1. Pods cordate at base.
          - \* Basal leaves appressed-stellate.
            - † Pubescence of young pods spreading; basal leaves angularly toothed....1. *P. didymocarpa*
            - †† Pubescence of young pods appressed; basal leaves entire or undulately toothed .....1a. var. *australis*
            - \*\* Basal leaves conspicuously lanate.....1b. var. *lanata*

2. Pods acute, obtuse or truncate at the base but scarcely cordate.  
 \* Basal leaves fiddle-shaped; plants of Colorado ..... 2. *P. vitulifera*  
 \*\* Basal leaves mostly entire; coarse plants of western Nebraska and the Dakotas ..... 3. *P. brassicoides*
- II. Basal leaves acute; blade lanceolate in outline.  
 1. Basal leaves mostly entire ..... 4. *P. acutifolia*  
 2. Basal leaves more or less pinnatifid ..... 5. *P. floribunda*
- β. Terminal sterile sboles developing from the rosette; pods pendent ..... 6. *P. Osterhoutii*
- b. Shoulders of the upper sinus angular, in young pods at least; pods furnished with keels along which the walls fold on drying ..... 7. *P. Newberryi*
- B. Mature pods strongly flattened laterally.  
 a. Pods obcordate in outline; replum about 5 mm. long ..... 8. *P. Geyeri*  
 b. Pods obreniform or broadly elliptical in outline; replum much longer.  
 a. Style 1-2 mm. long; base of pods obtuse or truncate ..... 9. *P. oregana*  
 β. Style about 5 mm. long; base of pods cordate ..... 10. *P. alpestris*

1. *P. didymocarpa* (Hook.) Gray in Wats. Bot. King's Exp. 20. 1871.

This species in its typical form is predominantly northern, occurring in the mountains from southern Canada to Wyoming and northern Utah.

1a. Var. *australis*, n. var.<sup>1</sup>

Basal leaves entire or undulately toothed; pubescence of leaves and young pods closely appressed.

Distribution: this variety replaces the typical form in southern Wyoming, Colorado, northern New Mexico, and in parts of Utah.

Specimens examined:

Wyoming: Sand Creek, Albany Co., June 1, 1900, *A. Nelson* 7026 (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); dry white hills, Dyer's Ranch, Carbon Co., June 21, 1901, *Goodding* 80 (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Cokeville, June 11, 1898, *A. Nelson* 4637 (Rky. Mt. Herb.); Ft. Bridger, June 9, 1898, *A. Nelson* 4602 (Rky. Mt. Herb.); Granger, June 13, 1898, *A. Nelson* 4688 (Rky. Mt. Herb.); Green River, May 30, 1897, *A. Nelson* 3032 (Rky. Mt. Herb.);

<sup>1</sup> *Physaria didymocarpa* (Hook.) Gray, var. *australis*, var. nov., foliis radicalibus integris vel sinuato-dentatis; siliquis junioribus adpresse pubescentibus. —Collected on gravel washes, Placerville, Colorado, July 23, 1917, *Payson* 1093 (Mo. Bot. Gard. Herb.), TYPE.

Ft. Steele, June 18, 1898, *A. Nelson* 4834 (Rky. Mt. Herb.); Green River, July 9, 1897, *Williams* (Rky. Mt. Herb.); Bates Creek, July 5, 1901, *Goodding* (Rky. Mt. Herb.).

Colorado: dry hills, Naturita, April 22, 1914, *Payson* 247 (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); foothills near Mancos, June 23, 1898, *Baker, Earle & Tracy* 75 (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Mack, May 27, 1908, *Jones* (Mo. Bot. Gard. Herb.); gravel washes, Placerville, July 23, 1917, *Payson* 1093 (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.), TYPE; dry, rocky slopes, Paradox, June 13, 1912, *Walker* 89 (Rky. Mt. Herb.); Mesa Verde National Park, 1913, *Haas* 40 (Rky. Mt. Herb.); hills near Montrose, May 3, 1913, *Payson* 75 (Rky. Mt. Herb.).

New Mexico: Aztec, April, 1899, *Baker* 356 (Rky. Mt. Herb.).

Utah: gravel, Cedar City, May 8, 1894, *Jones* 5202 (Mo. Bot. Gard. Herb.); near Fish Lake, May 17, 1875, *Ward* 48 (Mo. Bot. Gard. Herb.); east slope, Steptoe Valley, May 13, 1859, *H. Engelmann* (Mo. Bot. Gard. Herb.); Echo, May 7, 1890, *Jones* (Mo. Bot. Gard. Herb.); Mt. Nebo, Aug. 15, 1905, *Rydb. & Carlton* 7740 (Rky. Mt. Herb.); shale slopes, Brush Creek Canyon, Uintah Mts., July 17, 1902, *Goodding* 1279 (Rky. Mt. Herb.).

1b. Var. *lanata* A. Nels. Bull. Torr. Bot. Club 31 : 241. 1904.

*P. lanata* Rydb. Bull. Torr. Bot. Club 39 : 322. 1912.

Distribution: northern Wyoming and Montana.

2. *P. vitulifera* Rydb. Bull. Torr. Bot. Club 28 : 278. 1901.

*P. didymocarpa* Gray, Am. Jour. Sci. & Arts II. 33 : 243. 1862.

Distribution: in the mountains of Colorado.

3. *P. brassicoides* Rydb. Bull. Torr. Bot. Club 29 : 237. 1902.

Distribution: western Nebraska to southwestern North Dakota.

4. *P. acutifolia* Rydb. Bull. Torr. Bot. Club 28 : 279. 1901.

Distribution: in the mountains of Colorado.

5. *P. floribunda* Rydb. Bull. Torr. Bot. Club 28 : 279. 1901.  
Distribution: in the mountains of Colorado.

6. *P. Osterhoutii*, n. sp.<sup>1</sup>

Silvery stellate perennial from a simple or branched caudex; basal leaves small, blade lanceolate to hastate, usually acute, 5-10 mm. long, petiole 5-15 mm. long; cauline leaves from narrowly hastate or lanceolate to linear, 1-3.5 cm. long; caudex branches terminated by sterile, leafy soboles 1-4 cm. long; flowering stems lateral, decumbent-ascending, leafy, 8-12 cm. long; flowers yellow, conspicuous, fruiting inflorescence elongating; pedicels recurved, 1 cm. or more long; pods pendent, obcordate, base truncate or obtuse, apex deeply emarginate, cells inflated, rather loosely stellate; styles slender, about 4 mm. long, stigma capitate.

Distribution: north central Colorado.

Specimen examined:

Colorado: Kremmling, Grand Co., June 22, 1907, *Osterhout* 3477 (Rky. Mt. Herb.), TYPE.

Named in honor of Mr. Geo. E. Osterhout, of Windsor, Colorado, who was the first to recognize its specific distinction from the other known species of *Physaria*.

7. *P. Newberryi* Gray, Ives' Rept. Colo. River, pt. 4, 6. 1861.

*P. didymocarpa* (Hook.) Gray, var. *Newberryi* Jones, Proc. Calif. Acad. Sci. II. 5 : 624. 1895.

Distribution: northeastern New Mexico, southern Utah, northern Arizona, and southern Nevada.

8. *P. Geyeri* (Hook.) Gray, Gen. Illustr. 1 : 162. 1848.

Distribution: eastern Washington to western Montana.

9. *P. oregona* Wats., Proc. Am. Acad. 17 : 363. 1882.

<sup>1</sup> *Physaria Osterhoutii*, sp. nov., planta perennis undique indumento argenteo-stellata; caudicis ramis adscendentibus in soboles foliosas steriles terminantibus; foliis radicalibus petiolatis (petiolis 5-15 mm. longis) plus minusve hastatis, laminis lanceolatis plerumque acutis; foliis caulinis similibus sed angustioribus 1-3.5 cm. longis; caulibus foliosissimis 8-12 cm. longis; corolla flava; racemis remotifloris post anthesin; pedicellis fructiferis recurvatis circa 1 cm. longis; siliquis obcordatis basi truncatis vel obtusis, apice valde emarginatis laxe stellato-pubescentibus; stylo circa 4 mm. longo.—Collected at Kremmling, Grand Co., Colorado, June 22, 1907, *Osterhout* 3477 (Rky. Mt. Herb.), TYPE.



Distribution: eastern Oregon.

10. *P. alpestris* Suksdorf, West Am. Scientist 15 : 58. 1906.

Distribution: south central Washington.

### DITHYREA HARV.

This North American genus differs from the Mediterranean genus *Biscutella* in three conspicuous ways. *Dithyrea* has branched hairs, a stigma, the lobes of which extend over the middle of the carpels, and a replum of two distinct limbs which subtend a narrow, though evident, septum. *Biscutella*, on the other hand, exhibits unbranched hairs, a stigma, the lobes of which extend over the placentae, and a replum with fused limbs and obsolete septum. Although the two genera seem amply distinct, it appears impossible to accept Prantl's view that they belong in different sections of the family.

### KEY TO SPECIES AND VARIETIES

- A. Calyx spreading; pubescence of pods branched or stellate.
  - a. Leaves thick, lanceolate to linear, densely pubescent.
    - α. Leaves narrowly lanceolate to linear; stems branching, not strict. .... 1a. var. *Griffithsii*
    - β. Leaves broadly lanceolate; stems inclined to be strict.
      - I. Leaves cuneate at the base. .... 1. *D. Wislizenii*
      - II. Leaves truncate at the base; stems strict. .... 1b. var. *Palmeri*
  - b. Leaves thin, ovate or oblong, sparingly pubescent. .... 2. *D. membranacea*
- B. Calyx tubular; pubescence of pods of flattened unbranched cilia.
  - a. Style about 0.5 mm. long; mature pods 6-8 mm. broad.
    - α. Corolla dull white; inland plants. .... 3. *D. californica*
    - β. Corolla purplish; beach plants. .... 3a. var. *maritima*
  - b. Style nearly or quite 1 mm. long; mature pods 3-4 mm. broad. .... 4. *D. clinata*

1. *D. Wislizenii* Engelm. Wisliz. Tour N. Mexico, 95. 1848.

Distribution: western Texas, southern New Mexico, and adjacent Mexico.

*D. Wislizenii* in the aggregate exhibits within its large range three fairly distinct but more or less arbitrarily limited phases. Fortunately enough, the type was collected from near the geographical center of distribution and represents a form intermediate between the two varieties. The species in its typical form passes gradually on the east into the variety *Palmeri* and on the north and west into the

variety *Griffithsii*. Probably it is only in southern New Mexico and territory adjacent that the three phases are found together. Forms with glabrous pods occur occasionally throughout the species, and this character is in no way a specific one.

1a. Var. *Griffithsii* (Wooton & Standley), n. comb.

*D. Griffithsii* Wooton & Standley, Contr. U. S. Nat. Herb. 16: 124. 1913.

Distribution: western Texas, New Mexico, Arizona, southern Utah, and southern Nevada.

1b. Var. *Palmeri*, n. var.<sup>1</sup>

Pubescence very dense, almost velvety; stems about 5 dm. high, stout, branched upwards, branches strict, erect, leafy; cauline leaves thick, sessile or nearly so, ascending, lanceolate, 2-3.5 cm. long, entire or shallowly toothed, margins undulate.

Distribution: from southwestern Oklahoma, through northwestern Texas to southern New Mexico.

Specimens examined:

Oklahoma: Cimarron River, July 12, 1899, *White 155* (Mo. Bot. Gard. Herb.); sand by creek, near Granite, Greer Co., June 17, 1913, *Stevens 1036* (Mo. Bot. Gard. Herb.); Greer Co., July 18, 1901, *White* (Rky. Mt. Herb.); Red River Valley, July 12, 1903, *Duncan 79* (Mo. Bot. Gard. Herb.); Woodward Co., June 28, 1900, *White* (Rky. Mt. Herb.).

Texas: saline sands, Estelline, June 1, 1902, *Reverchon 2971* (Mo. Bot. Gard. Herb.); sandy ground near Colorado, June 9, 1900, *Eggert* (Mo. Bot. Gard. Herb.); salty sands, Colorado City, April, 1882, *Reverchon* (Mo. Bot. Gard. Herb.); sandy open ground, Big Spring, Howard Co., July 9, 1917, *Palmer 12493* (Mo. Bot. Gard. Herb.), TYPE.

New Mexico: Arroyo Ranch, near Roswell, May, 1903, *Griffiths 4266* (Mo. Bot. Gard. Herb.).

<sup>1</sup> *Dithyrea Walsenii* Engelm., var. *Palmeri*, var. nov., robusta plerumque stricta circa 5 dm. alta superne ramosa, pube ramosa brevi velutina; ramis foliosissimis strictis; foliis caulinis sessilibus vel fere sessilibus non patentibus lanceolatis basi truncatis 2-3.5 cm. longis.—Collected on sandy open ground, Big Spring, Howard Co., Texas, July 9, 1917, *Palmer 12493* (Mo. Bot. Gard. Herb.), TYPE.

This variety is named in honor of Mr. E. J. Palmer, from whose excellent Texan collections the type has been chosen.

2. *D. membranacea*, n. sp.<sup>1</sup>

Annual or biennial, green, rather sparsely pubescent with loose imperfect stellae or branching hairs; stems several from the root, sparingly branched, slender, decumbent, 3-6 dm. long; cauline leaves thin, narrowed abruptly at the base into a slender petiole about 1 cm. long, blade 3-4 cm. long, 2.5-3 cm. broad, irregularly ovate or oblong in outline, toothed or undulately lobed, apex broad and rounded; basal leaves unknown; sepals spreading, purplish; petals white, orbicular to oblong, abruptly narrowed to a very short claw and then somewhat dilated to point of insertion, margin irregular; filaments scarcely broadened at base; fruiting inflorescence elongated, pedicels about 12 mm. long, slender, divergent; pods apparently yet immature, erect or ascending, pubescent with two quite distinct sizes of branched hairs, substipitate, reticulated, and apparently lacking the margin so conspicuous in *D. Wislizenii*, cells nearly orbicular, about 4 mm. in diameter, replum about as long; style scarcely 1 mm. long, stigma subcapitate, slightly elongated over the middle of the carpels.

Distribution: Tamaulipas, Mexico.

Specimen examined:

Mexico: vicinity of Victoria, Tamaulipas, alt. about 320 m., February 1-April 9, 1907, *Dr. Edward Palmer 87* (Mo. Bot. Gard. Herb.), TYPE.

It is extremely interesting to find another species of *Dithyrea* very different from either of the two previously known. In general aspect it is much more like *D. californica* than *D. Wislizenii*, but in the characters of the flowers and fruit it is surely nearer the latter. The specific name was sug-

<sup>1</sup> *Dithyrea membranacea*, sp. nov., *D. Wislizenii* peraffinis sed caulibus foliisque viridibus parce pubescentibus; caulibus gracilibus decumbentibus 3-6 dm. longis; foliis caulinis membranaceis subovatis vel oblongo-ovatis circa 3-4 cm. longis 2.5-3 cm. latis plus minusve undulato-dentatis basi in petiolum circa 1 cm. longum abrupte attenuatis apice rotundatis; calycis lobis patentibus purpureo-tinctis; corolla alba; siliquis reticulatis non (?) marginatis.—Collected in the vicinity of Victoria, Tamaulipas, February 1-April 9, 1907, *Palmer 87* (Mo. Bot. Gard. Herb.), TYPE.

gested by the thin leaves which are in such striking contrast to those of the other species.

3. *D. californica* Harv. in Hook. Lond. Jour. Bot. 4: 77, pl. 5. 1845.

Distribution: southern Nevada, western Arizona, southern California, and northern Lower California.

3a. Var. *maritima* Davidson in Gray, Syn. Fl. N. Am. 1<sup>1</sup>: 123. 1895.

Distribution: "occasional along the seashore between Redondo and Port Ballona," southern California.

4. *D. clinata* Macbr. & Pays., n. sp.<sup>1</sup>

Slender-stemmed annual or biennial less than 3 dm. high; stems few, erect except at the subdecumbent base, simple or branched once toward the summit, sparsely pubescent; leaves subcinereous with branched hairs; basal leaves somewhat lyrate subpinnatifid, about 4 cm. long including the slender petiole, 5–10 mm. broad; stem-leaves few, gradually reduced upward, subentire or undulately lobed, ovate-oblong, the middle cauline, 1–1.5 cm. long, about 5 mm. broad, the uppermost about 5 mm. long and about 2.5 mm. broad; inflorescence about 1 dm. long; pedicels in fruit more or less recurved; petals white (?), scarcely 10 mm. long, exceeding the purplish sepals by about 2.5 mm.; style nearly 1 mm. long; fruit similar to that of *D. californica* but rarely half as large.

Distribution: unknown.

Specimen examined:

Lower California: Lagoon Head, March 6–15, 1889, Dr. Edward Palmer 824 (Gray Herb.), TYPE.

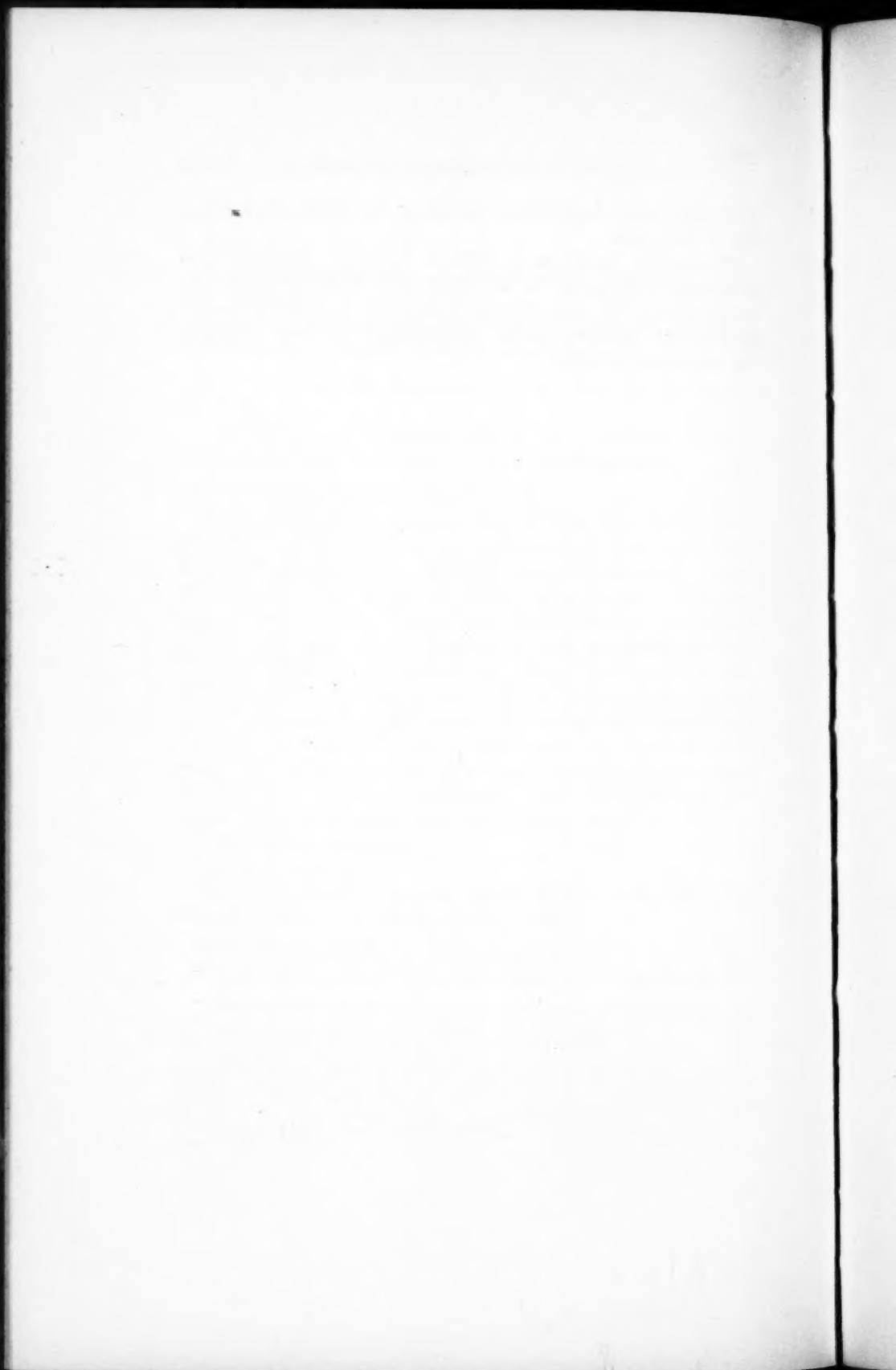
*Draba Standleyi* Macbr. & Pays., nom. nov.

*D. gilgiana* Wooton & Standley, Contr. U. S. Nat. Herb. 16:

<sup>1</sup> *Dithyrea clinata* Macbr. & Pays., spec. nov., planta annua vel biennis circa 3 dm. alta; caulibus gracilibus simplicibus parce pubescentibus; pilis ramosis; foliis cinereo-pubescentibus, radicalibus lyrate-subpinnatifidis circa 4 cm. longis 5–10 mm. latis basi in petiolum circa 1.5 cm. longum abrupte attenuatis, caulinis superioribus paucis gradatim reductis ovato-oblongis plus minusve sinuato-dentatis; racemis circa 1 dm. longis; pedicellis fructiferis plus minusve recurvatis; corolla ut videtur alba vix 10 mm. longa calycem superante 2.5 mm.; stylo fere 1 mm. longo; fructu ut apud *D. californicam* sed solum 3–4 mm. lato. —Collected at Lagoon Head, Lower California, March 6–15, 1889, Palmer 824 (Gray Herb.), TYPE.

124. 1913, not *D. Gilgiana* Muschler in Fedde, Rep. Nov. Sp. 3 : 212. 1906.

The use by Muschler in 1906 of the name *Gilgiana* for a seemingly valid species of *Draba* in Asia Minor precludes the acceptance of this name for the distinctive, more recently published, New Mexican plant. Accordingly we have renamed the American species.





## THE EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION

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Two earlier reports<sup>1</sup> from this laboratory seemed sufficiently to establish the point that a film of Bordeaux mixture increases the rate of transpiration of excised leaves of the castor bean, and likewise of potted tomato and potato plants. It was further indicated that other surface films, and to a slight extent dusts, may produce a similar, though on the whole lesser, accelerating effect. Nevertheless, it was felt that this work left incompletely answered questions relating both to the immediate and final effects of the spray, as well as to the relation of the acceleration found to night and day conditions, or to changes of environmental conditions in general. Again, it seemed eminently desirable to construct and employ in this work a rotating table, or transpirotaplane, by means of which it might be hoped to eliminate such errors as might arise from differing transpiration rates induced through the position of the plants in the different intervals, whether the plants observed were in the greenhouse or in the open. In the earlier experiments it had not been possible to take sufficient cognizance of these points, but immediately upon the presentation of the reports referred to above, further experiments were begun leading in the directions indicated. A variety of considerations prevented a prompt conclusion of this work. Meanwhile, there has appeared a paper by Martin<sup>2</sup> affording interesting and definite

<sup>1</sup> Duggar, B. M., and Cooley, J. S. The effect of surface films and dusts on the rate of transpiration. *Ann. Mo. Bot. Gard.* 1: 1-22. pl. 1. 1914; The effects of surface films on the rate of transpiration: experiments with potted potatoes. *Ibid.* 351-356. pl. 18. 1914.

<sup>2</sup> Martin, W. H. Influence of Bordeaux mixture on the rates of transpiration from abscised leaves and from potted plants. *Jour. Agr. Res.* 7: 529-548. 1916.

confirmation of the previous work, at the same time extending the findings of Duggar and Cooley regarding the accelerating effect of Bordeaux mixture and other surface films on the rate of transpiration of abscised leaves and potted plants. This work of Martin, conducted at the New Jersey Experiment Station, has been followed by a paper from Shive and Martin<sup>1</sup> on the effect of similar films upon the transpiring power of leaves, employing the method of standardized cobalt chloride paper as perfected through the work of Livingston and Shreve.<sup>2</sup> The method referred to has proved applicable to the investigation of problems of this nature, and affords further decisive evidence of the increased transpiring power of leaves sprayed with Bordeaux. Lutman,<sup>3</sup> in his careful study of Bordeaux mixture, has considered transpiration only in a subsidiary manner. He reviews the earlier work of the German observers, which, however, is based on rather inadequate experimentation, and seemed rather inclined to assume that increased transpiration might not be expected; yet his own experiments, so far as they go, indicate in general an increase in transpiration due to the Bordeaux film.

#### METHODS

In undertaking the present study it was decided to construct a rotating table, for the reasons given above, especially in an effort to eliminate the often rather serious error in transpiration studies, due to differences of exposure of the individual plants involved in the experiment. A rotating table was accordingly devised similar in principle to Livingston's<sup>4</sup> table for standardizing porous cup atmometers; in addition, however, to the revolution of the several plants about

<sup>1</sup> Shive, J. W., and Martin, W. H. The effect of surface films of Bordeaux mixture on the foliar transpiring power in tomato plants. *Plant World* 20: 67-86. *f. 1*. 1917.

<sup>2</sup> Livingston, B. E., and Shreve, E. B. Improvements in the method for determining the transpiring power of plant surfaces by hygrometric paper. *Ibid.* 19: 287-309. 1916.

<sup>3</sup> Lutman, B. F. Some studies on Bordeaux mixture. *Vt. Agr. Exp. Sta., Bul.* 196:1-80. *pt. 1-4. f. 1-11*. 1916.

<sup>4</sup> Livingston, B. E. A rotating table for standardizing porous cup atmometers. *Plant World* 15: 157-162. *f. 1-2*. 1912.

the central axis, each plant was made to turn upon the axis of its own platform.

The construction of the table was as follows:

A heavy cast-iron base, 5 inches in diameter and  $3\frac{1}{2}$  inches high, with a footing 12 inches in diameter and  $1\frac{1}{2}$  inches thick, supported a polished steel shaft of 1-inch diameter, 4 feet long. Four inches of this shaft were sunk into the top of the base, which had a small shoulder. On this shoulder rested a collar or ring enclosing a set of ball bearings which was slipped over the shaft, these carrying the greater part of the weight of the revolving system.

The 8 arms carrying the plant platforms consisted of  $1\times1\frac{1}{2}$ -inch channel irons, 4 feet long, arranged radially and bolted each with 2 bolts to a central plate 10 inches in diameter. This central plate was screwed to a short collar or outer shaft of iron tubing of  $\frac{3}{16}$ -inch thickness which slipped easily over the supporting steel central shaft without excessive play. On the portion of the collar below the central plate was bolted a sprocket wheel  $8\frac{1}{2}$  inches in diameter. The collar extended a little more than 1 inch above the central plate. Above this collar was imposed another short collar which was firmly screwed with set screws to the central steel shaft and did not bear upon any of the parts below; a sprocket wheel 3 inches in diameter was bolted to this second collar and a second ring of ball bearings fitted over the latter. On this ring then rested the second outer shaft, which revolved freely over the main steel axis, and extended a short distance above it.

The plant platforms consisted of discs of seasoned wood  $\frac{3}{4}$  inch thick and 7 inches in diameter. To the bottom of each was screwed a brass sprocket wheel  $2\frac{1}{2}$  inches in diameter. Each of such sprockets fitted over a cylindrical steel plug  $\frac{5}{8}$  inch in diameter, projecting  $\frac{1}{4}$  inch above the top of a rectangular cast-iron sleeve which slid along the channel iron. The platform could thus be set at any point along the arm, and was fixed by a set screw in one side of the sleeve.

Guy wires connected by steel eyelets from the upper end of the outer revolving shaft to an eyelet set in each channel

iron arm about 16 inches from the free end, with turnbuckles interposed, took up the strain on the arms resulting from heavy plants on the platforms.

One of the platforms, in addition to the brass sprocket below, had a second sprocket 4 inches in diameter, screwed to the latter. This second sprocket was connected by a link chain to the sprocket of the collar screwed to the central steel axis. A steel ladder chain running around the outer teeth of each platform sprocket completed the table proper.

The apparatus was then connected up, by means of a reducing gear attached to the shaft of a  $\frac{1}{4}$ -horsepower motor and an intermediate series of sprockets and chains for further reduction of speed, with the large sprocket wheel below the central plate of the table. As the whole table turned on its axis, and the small sprocket screwed to the central steel shaft remained stationary, this resulted in a movement of the link chain connecting this shaft sprocket to the second one on one of the plant platforms; in consequence, this platform turned slowly on its axis, and by means of the ring of the ladder chain transmitted the revolution to the other platforms.

The table as a whole revolved about once every 45 seconds and each plant platform about once every minute. Wherever necessary, the sag of the chains was taken up by supporting them with fiber rollers.

Without exception the experiments were carried out in the greenhouse, and the potted plants used had in all instances been grown under approximately similar conditions and then well accustomed to the environment of the experimental section of the greenhouse. Before being used in the experiments all exposed portions of every pot were coated with paraffin or wax seal. A thistle tube for watering and a bent tube for the release of air pressure were inserted into the soil, and the pot was sufficiently watered before the soil was likewise covered with the seal. When placed upon the platform of the rotating table each pot rested upon a saucer. The use of the rotating table made it somewhat inconvenient to employ any type of auto-irrigator, or constant moisture device, though

very careful attention was given to watering. This was done at intervals sufficiently frequent and in such quantity as to maintain a fairly constant water relation. In the case of all potted plants, where the load was considerable, weighings were made to within 1 gram on a Troemner balance. Moreover, in carrying out the weighings the observer used the same sequence, beginning always with plant No. 1 and concluding the 8 weighings in 6–8 minutes. Therefore, the observation intervals varied by a maximum of less than 2 minutes for the plants in any series, so that with intervals generally greater than 1 hour such variations are entirely negligible.

As in our earlier work, and as followed by subsequent investigators, observations were made on the basis of several to many standardization intervals prior to spraying; that is, the rates of the plants to be sprayed and of those to remain as the control were first determined, furnishing a basis for a ratio between controls and those to be Bordeauxed. Then after the application of the sprays to the plants designated for these—allowing sufficient time for the complete drying of the films—observations were again made on the control and the sprayed plants for a suitable number of intervals.

#### EXPERIMENTAL

The experimental data are included in a series of tables arranged in a manner as uniform as possible. In the first column at the left of each table is recorded a number by means of which to identify the various time intervals, or "runs"; in the second column the actual period of time covered by the interval is included (likewise ratios computed from the remaining columns), and then follow 8 columns—for the 8 plants involved in each experiment—numbered in order and giving the transpiration quantities for each. The letters accompanying the numbers signify the treatment proposed or given; thus, during any standardization interval K = control, B = Bordeaux, BL = Bordeaux with excess of lime, L = a lime wash, and BC = Bordeaux with excess of the copper salt. Other letters will be explained in connection



with special tables. In order readily to distinguish the quantities in the after-standardization intervals, that is, in the intervals after the application of the spray, the letters are written K', B', BL', etc.

The Bordeaux mixture was prepared as indicated in an earlier report, essentially the standard 4-6-50 formula of pathologists, while the mixture referred to as copper Bordeaux is the 6-4-50 formula, and that called lime Bordeaux is the standard Bordeaux diluted with an equal quantity of lime wash.

TABLE I  
(Series A.—Potted potatoes)  
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.  
DATA IN GRAMS

		1B*	2K†	3B	4K	5B	6K	7B	8K
I	8:20 A.M.—11:25 A.M. 1/9/17	19	20	13	11	13	22	15	8
	K:B = 61:60 = 1:98	Sunshine							
II	11:25 A.M.—3:25 P.M. 1/9/17	27	30	23	15	19	33	22	15
	K:B = 93:91 = 1:98	Sunshine							
III	3:25 P.M.—8:28 P.M. 1/9/17	6	4	6	6	3	7	7	5
	K:B = 22:22 = 1:1	Sunshine during early P.M. hours							
IV	8:28 P.M.—9:57 A.M. 1/10/17	16	13	17	10	7	16	18	11
	K:B = 50:58 = 1:1.16	Cloudy during early A.M. hours							
		1B'	2K'	3B'	4K'	5B'	6K'	7B'	8K'
V	4:00 P.M.—8:36 A.M. 1/11/17	49	11	38	15	24	17	52	17
	K':B' = 60:163 = 1:2.71	Sunshine at 4 P.M.							
VI	8:36 A.M.—12:31 P.M. 1/11/17	31	32	28	20	21	36	30	19
	K':B' = 107:110 = 1:1.03	Sunshine							
VII	12:31 P.M.—2:33 P.M. 1/11/17	21	28	17	14	15	24	21	14
	K':B' = 80:74 = 1:93	Sunshine							

\* B = Bordeaux mixture. † K = control.

If, in table I, the total water loss of the intervals before spraying is compared with the total after spraying, the ratio changes from 1.02 to 1.4, a percentage increase of 37 per cent to be attributed to the Bordeaux film. However, in view of the possible effects of environmental conditions, it is of in-



terest to compare some single intervals which are more or less comparable from the standpoint of length of interval and weather conditions. On this basis we may compare interval IV before standardization with interval V immediately after

TABLE II  
(Series B.—Potted potatoes)  
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.  
DATA IN GRAMS

		1K	2B	3K	4B	5K	6BL*	7B	8BL
I	3:27 P.M.—4:59 P.M. 2/12/17	14	8	8	6	10	6	6	9
	K:B:BL = 32:20:15 = 1:63:47								
II	4:59 P.M.—7:07 A.M. 2/13/17	26	15	23	10	15	14	16	27
	K:B:BL = 64:41:41 = 1:64:64								
III	7:07 A.M.—1:10 P.M. 2/13/17	37	23	20	24	18	19	16	23
	K:B:BL = 75:63:42 = 1:84:56								
IV	1:10 P.M.—4:13 P.M. 2/13/17	17	17	15	16	17	11	12	16
	K:B:BL = 49:45:27 = 1:92:55								
V	4:51 P.M.—9:14 A.M. 2/14/17	16	11	17	9	16	10	14	18
	K:B:BL = 49:34:28 = 1:69:57								
VI	9:14 A.M.—1:53 P.M. 2/14/17	43	24	37	33	34	21	26	29
	K:B:BL = 114:83:50 = 1:73:44 Cloudy								
VII	1:53 P.M.—3:10 P.M. 2/14/17	8	4	5	7	4	5	4	5
	K:B:BL = 17:15:10 = 1:88:59 Cloudy								
VIII	3:10 P.M.—6:02 P.M. 2/14/17	8	1	7	5	4	5	3	7
	K:B:BL = 19:9:12 = 1:47:63 Cloudy								
IX	6:02 P.M.—9:35 A.M. 2/15/17	20	14	23	13	17	15	22	23
	K:B:BL = 60:49:38 = 1:82:63								
X	9:35 A.M.—1:21 P.M. 2/15/17	28	39	34	35	31	29	23	30
	K:B:BL = 93:97:59 = 1:104:63								
XI	1:58 P.M.—4:52 P.M. 2/15/17	11	12	13	11	12	5	8	9
	K:B:BL = 36:31:14 = 1:86:39								
XII	4:52 P.M.—7:05 A.M. 2/16/17	10	5	6	5	7	7	9	6
	K:B:BL = 23:19:13 = 1:83:57								
XIII	7:05 A.M.—9:35 A.M. 2/16/17	46	40	36	31	18	33	22	7
	K:B:BL = 100:93:40 = 1:93:40 Sunshine								
XIV	1:26 P.M.—3:50 P.M. 2/16/17	17	20	16	19	15	14	11	12
	K:B:BL = 48:50:26 = 1:104:54 Sunshine								

\* BL = Bordeaux mixture with excess of lime.

TABLE II (Continued)  
(Series B.—Potted potatoes)  
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.  
DATA IN GRAMS

		1K'	2B'	3K'	4B'	5K'	6BL'	7B'	8BL'
XV	5:32 P.M.—7:10 A.M. 2/17/17	3	14	6	18	6	27	19	23
	K':B':BL' = 15:51:50 = 1:3.4:3.3								
XVI	7:10 A.M.—1:20 P.M. 2/17/17	64	52	40	53	47	32	32	45
	K':B':BL' = 151:137:77 = 1:97:51 Sunshine								
XVII	2:08 P.M.—7:57 P.M. 2/17/17	24	20	17	22	21	16	15	18
	K':B':BL' = 72:57:34 = 1:79:47 Sunshine during early P. M. hours								
XVIII	7:57 P.M.—8:26 A.M. 2/18/17	2	10	9	10	6	10	10	10
	K':B':BL' = 17:30:20 = 1:1.76:1.18								
XIX	8:26 A.M.—4:39 P.M. 2/18/17	29	27	19	23	13	14	15	18
	K':B':BL' = 61:66:32 = 1:1.08:52 Cloudy								
XX	7:10 A.M.—3:42 P.M. 2/19/17	31	56	61	52	35	47	29	34
	K':B':BL' = 127:137:81 = 1:1.08:64 Sunshine								

standardization, each interval extending throughout the night or somewhat longer. We then find that the ratio has changed from 1.16 to 2.71, or an increase of 133 per cent as a result of the surface film. During the second interval after standardization, VI, a day interval, the transpiration loss under conditions of continuous sunshine is very little more than during a similar interval, II, before standardization. Interval III before standardization is scarcely comparable with interval VII after standardization, but it is interesting to note that the increased water loss due to Bordeaux has now apparently disappeared, and the loss from these plants exhibits a ratio lower than in the control. Moreover, there is no interval after standardization which compares with the dull cloudy interval before standardization.

In table II considerable individual variation is exhibited, so that the relation of the K, B, and BL plants is not as constant as might be desired in the intervals before standardization. There seems to be a tendency for the K and BL loss to show a fair constancy, whereas the B plants frequently show a relatively high ratio during the day intervals and a

lower ratio during the night intervals. Since the conditions are the same for all the plants, this variation is unexplained. Leaving individual variation out of consideration, it will be seen that for the whole period of the observations the water loss is again higher for the plants sprayed with Bordeaux and lime Bordeaux than for the control. More interesting, however, are certain comparisons between single intervals before and after standardization. Assuming that the plants in the different lots before and after standardization are more nearly comparable in intervals which are relatively close together, we may compare the first interval after spraying, XV, which in other cases has shown marked increase as a result of the Bordeaux application, with interval XII before standardization, these two being night intervals of approximately equal length. Again, we find that the effect of the Bordeaux film during the first interval after spraying is very considerable, giving a percentage increase of 310, and that the Bordeaux lime preparation shows an increase of 479 per cent. On the other hand, if we compare the second interval after spraying under conditions of sunshine, XVI, with the last interval before spraying, XIV, we find a slightly diminished transpiration in the sprayed plants. The ratios of all subsequent intervals except one after spraying, XVII-XX, are nearly constant and approach the normal or average before standardization,—the exception being interval XVIII. The exceptional interval is a night period where again the ratio for sprayed plants is high. It seems well here to emphasize the fact that environmental conditions are obviously in some way important in determining the increased transpiration due to surface films.

The data given for series C in table III is noteworthy for several reasons. In the first place, it will be seen that in the several intervals of standardization the L group of plants exhibits a relative falling off in the rate of transpiration. There was no apparent cause for this, as the soil conditions were as moist as in the other pots, and evidence of flagging was entirely lacking. In the second place, after spraying the water loss of the B' and BC' plants is very great during interval

IV, this interval being largely a night period. During the next interval (a day period), with conditions bright and warm, there is practically a return to the normal or standardization rate for the B' and BC' plants as compared with

TABLE III  
(Series C.—Potted tomatoes)  
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.  
DATA IN GRAMS

		1K	2B	3BC*	4L†	5BC	6B	7K	8L
I	3:50 P.M.—9:10 A.M. 1/12/17	26	23	27	27	31	33	34	36
	K:B:BC:L = 60:56:58:63 = 1:93:97:1.05 Sunshine P.M.; cloudy A.M.								
II	9:10 A.M.—12:37 P.M. 1/12/17	28	29	25	20	29	33	29	29
	K:B:BC:L = 57:62:54:49 = 1:1.09:95:86 Sunshine, some clouds								
III	12:37 P.M.—3:44 P.M. 1/12/17	24	30	23	13	27	28	20	15
	K:B:BC:L = 44:58:50:28 = 1:1.33:1.14:45 Sunshine, some clouds								
		1K'	2B'	3BC'	4L'	5BC'	6B'	7K'	8L'
IV	5:22 P.M.—9:13 A.M. 1/13/17	22	84	75	29	84	92	26	37
	K':B':BC':L' = 48:176:159:66 = 1:3.67:3.31:1.38 Sunshine A.M.								
V	9:13 A.M.—1:46 P.M. 1/13/17	41	45	40	32	38	31	40	29
	K':B':BC':L' = 81:76:78:61 = 1:94:96:75 Sunshine, temperature high								
VI	3:37 P.M.—10:10 A.M. 1/14/17	32	61	55	33	57	59	37	34
	K':B':BC':L' = 69:120:112:67 = 1:1.74:1.62:97 Sunshine, temperature high								
VII	10:10 A.M.—1:38 P.M. 1/14/17	29	34	23	21	20	16	25	28
	K':B':BC':L' = 54:50:43:49 = 1:93:80:91 Sunshine, temperature high								
VIII	1:38 P.M.—5:09 P.M. 1/14/17	15	16	11	13	12	13	12	---
	K':B':BC':L' = 27:29:23:(29 est.) = 1:1.07:85:1.07 Sunshine, temp. high								
IX	5:09 P.M.—10:08 A.M. 1/15/17	16	52	45	28	30	35	18	---
	K':B':BC':L' = 34:87:75:(60 est.) = 1:2.56:2.21:1.76 Cloudy A.M.								

\* BC = Bordeaux with excess of the copper salt. † L = lime wash.

the control. Interval VI, again largely a twilight and night period, shows a rise in the rate in favor of the B' and BC' sprayed plants, followed again by day intervals in which the normal is approached. It was this series in particular, which was conducted prior to series B, which suggested so definitely the importance of conditions in modifying the amount of the transpiration quantities after spraying. In the preceding

discussion of ratios mention has not been made of the L lot of plants, but owing to the successive falling off in their rate of water loss during the standardization interval, it was felt that this lot could not be considered entirely normal. Never-

TABLE IV  
(Series D.—Potted tomatoes)  
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.  
DATA IN GRAMS

		1B	2Fe*	3B	4Fe	5Al†	6Mg‡	7Al	8Mg
I	8:31 A.M.—3:42 P.M. 1/19/17	21	29	20	18	36	26	27	28
	B:Fe:Al:Mg = 41:47:53:54 = 1:1.15:1.54:1.32	Sunshine							
II	3:42 P.M.—9:35 A.M. 1/20/17	11	12	11	7	12	13	11	13
	B:Fe:Al:Mg = 22:19:23:26 = 1:86:1.05:1.18	Sunshine							
III	9:35 A.M.—11:17 A.M. 1/20/17	6	9	6	8	11	7	7	10
	B:Fe:Al:Mg = 12:17:18:17 = 1:1.42:1.5:1.42	Sunshine							
		1B'	2Fe'	3B'	4Fe'	5Al'	6Mg'	7Al'	8Mg
IV	1:50 P.M.—10:12 P.M. 1/20/17	16	17	16	15	25	35	22	34
	B':Fe':Al':Mg' = 32:32:47:69 = 1:1:1.47:2.16	Cloudy							
V	10:12 P.M.—12:45 P.M. 1/21/17	25	33	22	21	28	38	33	38
	B':Fe':Al':Mg' = 47:54:61:76 = 1:1.15:1.3:1.62	Intermittent sunshine							
VI	10:48 P.M.—9:24 A.M. 1/22/17	16	19	11	12	15	17	17	20
	B':Fe':Al':Mg' = 27:31:32:37 = 1:1.15:1.19:1.37								
VII	9:24 A.M.—3:15 P.M. 1/22/17	23	21	21	17	12	15	18	22
	B':Fe':Al':Mg' = 44:38:30:37 = 1:86:68:84								

\*Fe = film of ferric hydrate. †Al = film of aluminum hydrate. ‡Mg = film of magnesium hydrate.

theless, it exhibits on the whole much the same change of ratio with change of conditions as the B' and BC' lots. Here again, as in our earlier experiments, the effect of the lime film has not generally been to increase the transpiration loss to the same extent as the copper films.

The data for series D are introduced with some hesitation, owing to the fact that at the close of the experiment all of the plants except one of those sprayed with Bordeaux mixture showed some injury, the extent of this being the wilting or death of from 1 to 4 leaves of each plant. Nevertheless,



some suggestions are evident as a result of this work. As compared with Bordeaux mixture, the films of iron, aluminum, and magnesium hydrate exhibit in the earlier intervals after standardization a rate which is on the whole equal to or greater than that of the Bordeaux-sprayed plants. In the last interval, however, there is a distinct falling off in all of

TABLE V  
(Series E.—Potted tomatoes)  
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.  
DATA IN GRAMS

		1B	2B	3RB*	4RB	5K	6K	7RB	8K
I	1:12 P.M.-4:49 P.M. 2/23/17	36	45	41	49	40	48	44	51
	K:B:RB = 139:81:134 = 1:58:96	Sunshine, becoming cloudy							
II	4:49 P.M.-7:00 A.M. 2/24/17	33	55	30	34	38	34	38	40
	K:B:RB = 112:88:102 = 1:79:91	Hazy at 7 A.M.							
III	7:00 A.M.-2:55 P.M. 2/24/17	93	73	77	66	63	86	117	91
	K:B:RB = 240:166:260 = 1:69:108	Intermittent sunshine							
IV	3:25 P.M.-5:38 P.M. 2/24/17	5	2	4	3	3	2	5	4
	K:B:RB = 9:7:12 = 1:78:133	Hazy							
V	5:38 P.M.-8:09 A.M. 2/25/17	29	28	28	25	25	32	35	31
	K:B:RB = 88:57:88 = 1:65:1	Very hazy late P.M.							
		1B'	2B'	3RB'	4RB'	5K'	6K'	7RB'	8K'
VI	11:09 A.M.-5:36 P.M. 2/25/17	109	83	95	81	46	133	112	134
	K':B':RB' = 313:192:288 = 1:61:92	Sunshine							
VII	5:36 P.M.-7:14 A.M. 2/26/17	11	6	7	7	4	8	10	4
	K':B':RB' = 16:17:24 = 1:1.06:1.50								
VIII	7:14 A.M.-1:00 P.M. 2/26/17	49	29	32	34	18	55	47	45
	K':B':RB' = 118:75:113 = 1:64:96	Sunshine							
IX	1:26 P.M.-4:22 P.M. 2/26/17	24	19	16	14	21	29	22	29
	K':B':RB' = 79:43:52 = 1:54:66	Dull, becoming cloudy							
X	4:22 P.M.-7:10 A.M. 2/27/17	34	27	32	32	14	25	46	22
	K':B':RB' = 61:61:110 = 1:1:1.80	Cloudy							
XI	7:44 A.M.-4:07 P.M. 2/27/17	44	35	29	32	45	61	35	58
	K':B':RB' = 164:79:96 = 1:48:52	Cloudy							
XII	4:07 P.M.-7:11 A.M. 2/28/17	42	33	37	35	29	29	53	34
	K':B':RB' = 92:75:125 = 1:82:136								

\* RB = red Bordeaux (erythrosin added).



the other lots as compared with the Bordeaux. It may perhaps be taken to suggest that the increased rate of transpiration of such films may in a measure be related to incipient injury, the rate being relatively high until this injury leads to wilting or death of a certain proportion of the leaves.

Series E was arranged with relatively old, potted tomato plants which had been cut back and had grown considerably "bunched." The greenhouse was maintained under the usual

TABLE VI  
(Series F.—Potted marguerites)  
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.  
DATA IN GRAMS

		1B	2R*	3B	4K	5R	6B	7K	8R
I	4:50 P.M.—9:25 A.M. 1/24/17	33	36	22	35	18	38	19	35
	K:B:R = 54:93:89 = 1:1.72:1.65								
II	10:10 A.M.—4 P.M. 1/24/17	124	129	121	147	57	135	75	158
	K:B:R = 222:380:344 = 1:1.71:1.55								
		1B'	2R'	3B'	4K'	5R'	6B'	7K'	8R'
III	4:47 P.M.—9:08 A.M. 1/25/17	15	24	17	12	23	27	14	18
	K':B':R' = 26:59:65 = 1:2.27:2.5								
IV	10:18 A.M.—3:03 P.M. 1/26/17	61	75	54	60	72	72	86	67
	K':B':R' = 146:187:214 = 1:1.28:1.47								

\* R = resin Bordeaux.

conditions during intervals I—III and VIII—XII. During intervals IV—VII the walls and floors of the house were drenched morning and evening, and a small stream of water kept flowing through the house in an effort to maintain higher humidities. This was fairly successful except in interval VI, when the bright sunshine and high temperature made it difficult of accomplishment. During interval IV, moreover, the transpiration quantities are so small that the ratios are of questionable value. In this series three plants were treated with a reddened Bordeaux mixture, this being made by the addition of erythrosin to the usual Bordeaux until a deep red color was produced. The treated plants were sprayed copiously; in fact, until the mixture streamed from the plants.

		1B	2K	3B	4K	5B	6K	7B	8K
I	4:30 P.M.-5:32 P.M. 1/17/18	4	8	3	9	5	6	3	2
	K:B = 25:15 = 1:60	Bright at 4:30							
II	5:32 P.M.-7:34 P.M. 1/17/18	6	10	10	2	4	8	3	2
	K:B = 22:23 = 1:1.05								
III	7:34 P.M.-10:34 P.M. 1/17/18	6	10	11	10	5	11	2	4
	K:B = 35:24 = 1:69								
IV	10:34 P.M.-7:01 A.M. 1/18/18	15	26	21	29	15	32	11	10
	K:B = 97:62 = 1:64								
V	7:34 A.M.-8:41 A.M. 1/18/18	2	5	3	7	2	6	2	3
	K:B = 21:9 = 1:43	Sunshine by 8 A.M.							
VI	8:41 A.M.-9:41 A.M. 1/18/18	6	5	6	7	8	8	2	8
	K:B = 28:22 = 1:79	Sunshine							
VII	9:41 A.M.-10:41 A.M. 1/18/18	11	12	9	11	11	11	8	8
	K:B = 42:39 = 1:93	Sunshine							
VIII	10:41 A.M.-11:41 A.M. 1/18/18	12	16	15	17	22	15	15	15
	K:B = 63:64 = 1:1.02	Sunshine							
IX	11:41 A.M.-12:41 P.M. 1/18/18	13	18	12	19	15	14	7	15
	K:B = 66:47 = 1:71	Sunshine							
X	12:41 P.M.-1:41 P.M. 1/18/18	11	18	13	16	15	17	10	12
	K:B = 63:49 = 1:78	Sunshine							
XI	2:00 P.M.-3:00 P.M. 1/18/18	11	15	10	17	11	14	11	14
	K:B = 60:43 = 1:72	Sunshine							

TABLE VII (Continued)

		1B'	2K'	3B'	4K'	5B'	6K'	7B'	8K'
XII	4:30 P.M.-5:30 P.M. 1/18/18	12	5	10	4	13	4	12	0
	$K':B' = 13:47 = 1:3.62$								
XIII	5:30 P.M.-7:32 P.M. 1/18/18	9	2	12	4	13	4	10	0
	$K':B' = 10:44 = 1:4.4$								
XIV	7:32 P.M.-10:32 P.M. 1/18/18	13	4	8	3	19	4	15	2½
	$K':B' = 13:55 = 1:4.07$								
XV	10:51 P.M.-7:15 A.M. 1/19/18	31	10	24	7	40	9	32	8
	$K':B' = 34:127 = 1:3.74$								
XVI	7:44 A.M.-8:44 A.M. 1/19/18	9	7	5	7	4	9	5	4
	$K':B' = 27:23 = 1:85$	Glass frosted during this interval							
XVII	8:44 A.M.-9:44 A.M. 1/19/18	9	8	7	10	10	8	9	6
	$K':B' = 32:35 = 1:1.09$	Sunshine							
XVIII	9:44 A.M.-10:44 A.M. 1/19/18	14	17	11	14	15	15	14	14
	$K':B' = 60:54 = 1:90$	Sunshine							
XIX	10:44 A.M.-11:45 A.M. 1/19/18	9	11	9	15	14	9	12	13
	$K':B' = 48:44 = 1:92$	Cloudy during most of interval							
XX	11:45 A.M.-12:45 P.M. 1/19/18	13	14	10	8	12	14	8	13
	$K':B' = 49:43 = 1:88$	Cloudy							
XXI	12:45 P.M.-1:49 P.M. 1/19/18	11	13	12	13	12	11	11	11
	$K':B' = 48:46 = 1:96$	Cloudy							
XXII	1:49 P.M.-2:50 P.M. 1/19/18	7	7	4	9	3	7	6	7
	$K':B' = 30:20 = 1:67$	Cloudy							
XXIII	2:50 P.M.-3:50 P.M. 1/19/18	7	4	2	2	9	5	6	2
	$K':B' = 13:24 = 1:1.85$	Cloudy							

liminary trial it was seen that the usual Bordeaux mixtures would not adhere well, so that in addition to this a resin Bordeaux was employed. All treated plants were sprayed heavily. The transpiration quantities were remarkably uniform in the standardization intervals, and after spraying the increased transpiration for the sprayed plants was considerable, the ratio for Bordeaux changing from 1:71 to 1:2.27. The group treated with the resin Bordeaux gave somewhat greater transpiration loss during the same interval. Unfortunately, after this first interval, and with the higher temperature of the greenhouse during the day, injury began to

		1B	2K	3B	4K	5B	6K	7B	8K
I	10:00 A.M.–11:00 A.M. 10/25/17	18	18	----	15	21	12	18	11
	K:B = 56:57 = 1:1.02	Cloudy							
II	11:00 A.M.–12:04 A.M. 10/25/17	13	16	----	12	18	9	12	2
	K:B = 39:43 = 1:1.10	Cloudy							
III	12:04 A.M.–1:00 P.M. 10/25/17	16	19	----	15	18	12	19	10
	K:B = 56:53 = 1:95	Cloudy							
IV	1:00 P.M.–2:09 P.M. 10/25/17	12	13	----	13	17	17	5	1
	K:B = 44:34 = 1:77	Cloudy							
V	2:09 P.M.–3:08 P.M. 10/25/17	11	11	----	11	17	6	13	8
	K:B = 36:41 = 1:1.14	Cloudy							
VI	4:01 P.M.–7:15 A.M. 10/26/17	44	52	----	32	61	50	28	24
	K:B = 158:133 = 1:84	Cloudy							

TABLE VIII (Continued)

		1B'	2K'	3B'	4K'	5B'	6K'	7B'	8K'
VII	10:06 A.M.—11:06 A.M. 10/26/17	10	11	----	11	8	11	9	9
	K':B' = 42:27 = 1:64	Cloudy							
VIII	11:06 A.M.—12:06 A.M. 10/26/17	9	17	----	15	11	12	9	7
	K':B' = 51:29 = 1:57	Cloudy							
IX	12:06 A.M.—1:06 P.M. 10/26/17	17	21	----	19	22	21	14	19
	K':B' = 80:53 = 1:66	Cloudy to intermittent sunshine							
X	1:06 P.M.—2:06 P.M. 10/26/17	23	36	----	29	28	29	24	19
	K':B' = 113:75 = 1:67	Sunshine							
XI	2:38 P.M.—3:38 P.M. 10/26/17	32	29	----	30	30	24	24	18
	K':B' = 101:86 = 1:85	Sunshine							
XII	3:38 P.M.—4:38 P.M. 10/26/17	18	19	----	18	21	17	18	8
	K':B' = 62:57 = 1:92	Sunshine							
XIII	4:38 P.M.—7:10 A.M. 10/27/17	38	51	----	28	62	63	35	32
	K':B' = 174:135 = 1:78	Rain							
XIV	7:59 A.M.—8:59 A.M. 10/27/17	13	10	----	11	11	6	11	9
	K':B' = 36:35 = 1:97	Cloudy							
XV	8:59 A.M.—9:59 A.M. 10/27/17	15	23	----	24	19	20	17	16
	K':B' = 83:51 = 1:61	Cloudy							
XVI	9:59 A.M.—10:59 A.M. 10/27/17	18	15	----	15	21	18	14	19
	K':B' = 67:53 = 1:79	Cloudy							
XVII	10:59 A.M.—12:00 M. 10/27/17	29	36	----	35	35	34	29	27
	K':B' = 132:93 = 1:70	Cloudy to intermittent sunshine							
XVIII	12:00 M.—1:02 P.M. 10/27/17	39	42	----	43	53	42	45	33
	K':B' = 160:137 = 1:86	Sunshine							
XIX	1:02 P.M.—2:01 P.M. 10/27/17	47	48	----	43	56	48	39	39
	K':B' = 178:142 = 1:79	Sunshine							
XX	2:46 P.M.—3:46 P.M. 10/27/17	37	48	----	38	45	39	39	32
	K':B' = 157:121 = 1:77	Sunshine							
XXI	3:46 P.M.—4:46 P.M. 10/27/17	21	22	----	19	28	22	23	17
	K':B' = 80:72 = 1:90	Sunshine							

spraying, an immediate and pronounced increase in the transpiration loss over that at approximately the same time of day in intervals I—III, the average ratio changing from 1:.76 to 1:4.0. This increase was also maintained for the interval covering the remainder of the first night after spraying, and

subsequent to that time there was little or no indication of any increased transpiration loss due to spraying as the day advanced, at least up to 2:50 P. M., the beginning of interval XXIII. During the last-named interval, however, there were some indications of wilting, and the rise in transpiration of the sprayed plants might as well be attributed to accidental conditions as to an effect due to the spray. The experiment was therefore discontinued at that point.

Up to October, 1917, the data which had been obtained related merely to mesophytic dicotyledonous plants, and it was determined to include a series with plants of somewhat different water requirements. The common umbrella plant, *Cyperus esculentus*, seemed to offer favorable material, inasmuch as it differed not only structurally from the species previously employed, but also promised to maintain itself well under conditions of abundant water supply to the roots.

The plants used in series H were about  $\frac{1}{2}$  m. in height, and all had previously been grown under similar conditions. In order to supply sufficient water, and at the same time to cover effectively the development of chaff and old stems in the crowns of the plants, the soil and basal parts of the plant in each pot were covered with wadded absorbent cotton. After thoroughly moistening soil and cotton the surface of the latter and the exposed parts of the pots, as usual, were covered with paraffin.

The standardization intervals included one day of cloudy weather, and after standardization observations were made for  $1\frac{1}{2}$  days, during which the conditions afforded both cloudiness and sunshine. It is noteworthy that for several intervals after spraying there is a lower rate of water loss from the sprayed plants than from the controls. The night interval presents no material change as contrasted with the average of adjacent day intervals, and throughout the period following the spraying the Bordeaux plants exhibit the lower rate of water loss. Discussion of this unusual condition will be postponed for the general consideration of the results obtained in all the experiments.



TABLE IX  
(Series J.—Castor bean leaves)  
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.  
DATA IN GRAMS

		1K	2B	3K	4B	5K	6B	7K	8B
I	10:46 A.M.—11:18 A.M. 9/24/17	2.6	5.0	8.7	9.1	0.3	8.4	5.1	8.8
	K:B = 16.7:31.3 = 1:1.87	Sunshine							
II	11:18 A.M.—11:48 A.M. 9/24/17	7.1	6.9	13.4	8.0	1.0	12.2	6.5	11.8
	K:B = 28.0:38.9 = 1:1.35	Sunshine							
III	11:48 A.M.—12:18 P.M. 9/24/17	5.1	7.7	11.5	6.6	1.0	14.5	7.9	12.2
	K:B = 25.5:41.0 = 1:1.61	Sunshine							
IV	12:18 P.M.—12:49 P.M. 9/24/17	11.2	6.5	7.0	5.5	1.3	10.3	6.2	9.0
	K:B = 25.7:31.3 = 1:1.22	Sunshine							
V	12:49 P.M.—1:45 P.M. 9/24/17	6.4	14.3	7.5	8.9	1.1	22.1	15.7	18.1
	K:B = 30.7:63.4 = 1:2.07	Sunshine							
		1K'	2B'	3K'	4B'	5K'	6B'	7K'	8B'
VI	3:21 P.M.—3:55 P.M. 9/24/17	1.2	6.2	3.2	4.2	0.7	12.3	8.0	8.6
	K':B' = 13.1:31.3 = 1:2.39	Sunshine							
VII	3:55 P.M.—4:29 P.M. 9/24/17	1.3	6.1	3.5	4.0	1.0	9.1	4.2	6.6
	K':B' = 10.0:25.8 = 1:2.58	Sunshine							
VIII	4:29 P.M.—5:04 P.M. 9/24/17	0.3	4.0	1.4	2.9	0.8	6.9	3.6	5.7
	K':B' = 6.6:19.5 = 1:2.95	Sunshine							
IX	5:04 P.M.—7:06 P.M. 9/24/17	1.6	7.0	2.1	5.8	2.0	12.1	5.5	8.3
	K':B' = 11.2:33.2 = 1:2.96								
X	7:06 P.M.—9:08 P.M. 9/24/17	1.7	4.0	1.3	5.2	1.5	6.9	4.0	5.1
	K':B' = 8.5:21.2 = 1:2.49								
XI	9:08 P.M.—7:03 A.M. 9/25/17	3.3	4.5	1.6	5.4	2.2	8.5	4.1	6.6
	K':B' = 11.2:25.0 = 1:2.23								
XII	7:03 A.M.—9:10 A.M. 9/25/17	1.6	11.4	5.0	8.5	1.4	7.5	10.4	15.0
	K':B' = 18.4:42.4 = 1:2.34	Weak sunshine							
XIII	9:10 A.M.—10:14 A.M. 9/25/17	2.9	11.2	2.4	7.1	1.3	21.4	11.9	18.4
	K':B' = 18.5:58.1 = 1:3.14	Sunshine							
XIV	10:14 A.M.—11:09 A.M. 9/25/17	3.6	7.3	2.2	7.1	1.2	23.1	14.4	21.3
	K':B' = 21.4:58.8 = 1:2.75	Sunshine							

It had been intended to repeat the experiments with excised leaves under various environmental conditions, but the high temperature prevailing when the material was ready in the

early fall rendered this impossible. Leaves of the castor bean, which in our earlier work had been found favorable for studies of this kind, were procurable in large number, but under the conditions maintaining in the greenhouse they proved subject to great fluctuations and to severe wilting. In many cases the leaves wilted in test chambers where the atmosphere was kept fairly moist, and the indications were that the cause might lie in the movement of viscous materials into the conducting channels. Nevertheless, one completed series was maintained under satisfactory conditions and the results are shown in table ix. The leaf stems were inserted through one mouth of a Wolff bottle into a weak Crone solution, movement of the leaves with the rotation of the table, when this occurred, being prevented by means of a lump of plasticene. In this case, however, weighings were made on a trip balance, weighing accurately to .1 gram.

From the data presented it will be seen that the sprayed plants exhibit an increase in the transpiration loss throughout all intervals of the experiment. In this case the increased water loss in the night interval is no more pronounced than during any other interval. The results here are in complete accord with those previously reported from this laboratory, and it would seem reasonable to anticipate that some general explanation may be advanced to account for the striking differences noted in these experiments as between excised leaves, on the one hand, and potted plants, such as the potato, tomato, and tobacco, on the other.

#### DISCUSSION AND SUMMARY

The data presented in this paper offer a mass of additional proof to establish the point that a film of Bordeaux mixture or of certain other materials of similar physical characteristics influence, often to a marked degree, the rate of water loss from the plant. Although the work accomplished does not yet include as many types of plants as might be wished, nor are the conditions of the environment so completely measured or controlled that the relation of this increased water loss to environmental factors may be clearly defined, yet that both

plant type and summation of conditions are factors of importance seems a well-warranted conclusion, as will be developed below.

The results may be discussed in three categories, in respect to the plant material employed. In the first type of material the usual mesophytic potted plant has constituted the experimental object; in the second, a plant of xerophytic surface modifications, *Cyperus esculentus*; and third, abscised leaves of castor beans. Without exception, the potted plants in the first category furnished consistent evidence that under the conditions of our experiments increase in the rate of transpiration occurs mainly, if not entirely, during the night intervals. There may be little or no change in the rate of transpiration during the day intervals, and, to a considerable extent, at least, this is independent of slight changes in weather conditions,—some of the experiments having been conducted in bright sunshine, others in cloudy weather, and in still other cases different intervals in the same series have furnished varied conditions. Nevertheless, the fact that the night interval has invariably exhibited, in respect to the sprayed plants, a transpiration increase, makes it clear that in some way the sum of night and day conditions is responsible for the increased water loss. Attempts to increase or diminish the humidity in the greenhouse by flooding with water has not resulted in any indications which alone might explain the observed phenomenon.

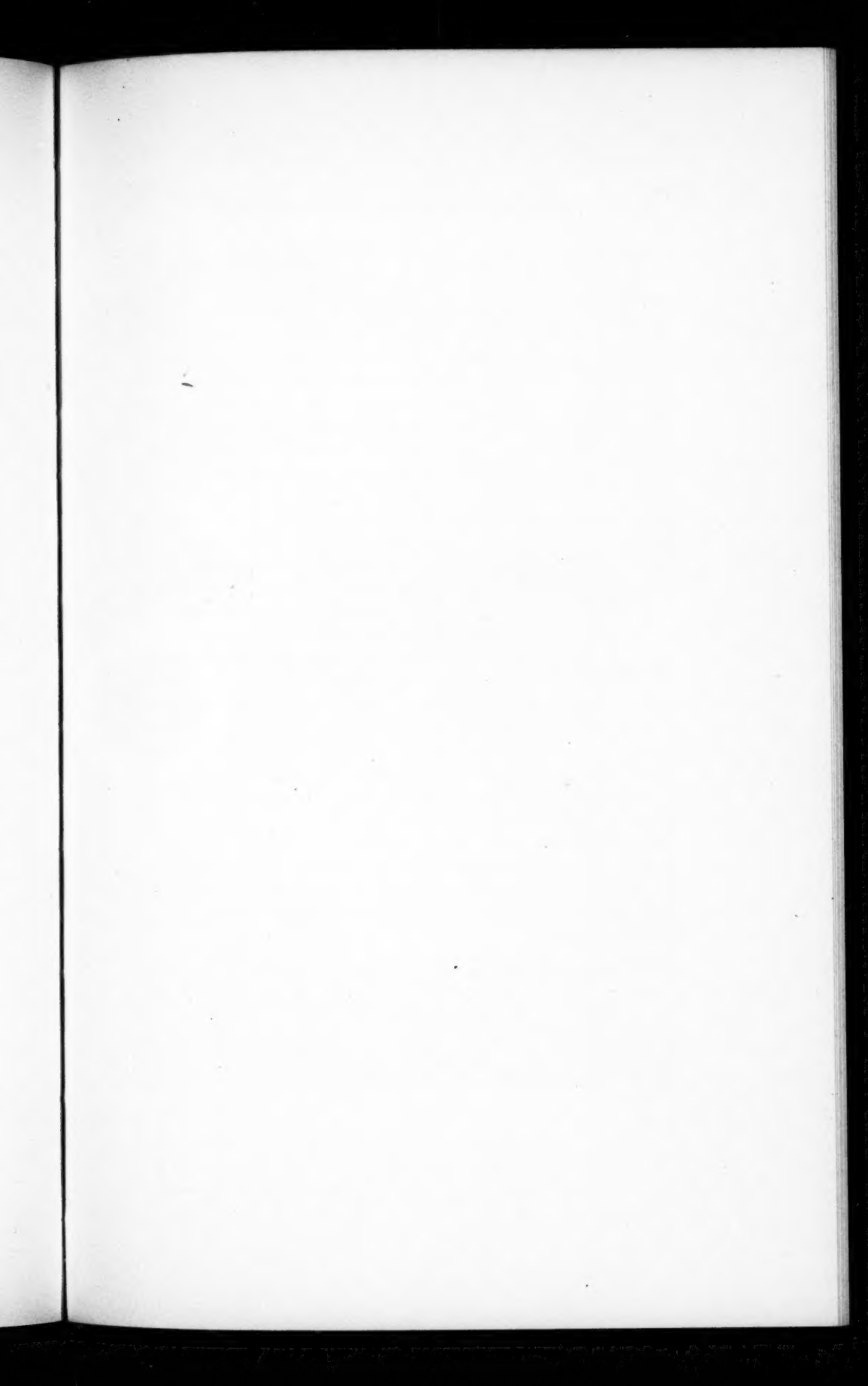
The greenhouse was subject to a rise and fall of temperature from midnight to midday, amounting to from 7 to 15° C. It has repeatedly been noticed that under such greenhouse conditions seedlings exhibit the phenomenon of guttation to some degree, often to a very high degree. Now if it may be assumed that the potted plants experimented upon were subject each night to conditions inducing guttation, or at least incipient guttation, this condition might be made use of to explain the phenomenon in the following way: A film of Bordeaux mixture on the surface of a plant in a state of guttation would probably act more or less as a bibulous surface, taking water directly from the interior of the plant, through

at least some continuous water channels established by means of the open water-suffused stomata. Under such conditions it seems fair to assume that the water would spread through the film of Bordeaux mixture, and the evaporating surface would thereby be greatly increased. On the other hand, during the day, as this state of incipient guttation might give way to a condition in which the interchange between the inner and outer atmosphere is governed wholly by the diffusion of water vapor, the presence of an absorbent surface film would have little, or at least far less, power to increase the evaporating surface, or in any other known manner to facilitate evaporation.

Again, taking the case of *Cyperus*, an explanation of the failure of the surface film to increase the transpiration rate might then be found both in the fact that the stomatal openings are exceedingly small, and that the air space of the leaf tissue is very limited in extent. In all probability, with such material, a state approaching guttation would be realized with great difficulty, if at all, and a "clogging" of the stomata might indeed tend to inhibit transpiration.

The excised leaves which are able to maintain themselves at all might be expected to exhibit very different water relations, and it is not possible from the data at hand to conclude that in this case there is in reality any possibility of a state of incipient guttation. This is, however, possible. At any rate, the writers have found no satisfactory explanation of the results obtained except the one just discussed. Some phases of this explanation are susceptible of direct experimentation and in further work it is proposed to subject the matter to critical test. For the present it is offered as a suggestion merely.

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## EXPLANATION OF PLATE

## PLATE 10

General view of rotating "table" arranged with *Cyperus*. The thermo-hygrograph employed—removed from sheltered stand—is also shown.



DUGGAR AND BONNS—RATE OF TRANSPIRATION

